This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

B 1,069,046

LIBRARY OF THE
UNIVERSITY OF MICHIGAN

QE
127
.A2

THE GEOLOGICAL

AND

NATURAL HISTORY SURVEY

OF

MINNESOTA.

THE SEVENTEENTH ANNUAL REPORT.

FOR THE YEAR 1888.

From

N. H. WINCHELL,
STATE GEOLOGIST.

ST. PAUL, MINN.:
THE PIONEER PRESS COMPANY
1889.

THE GEOLOGICAL

AND

NATURAL HISTORY SURVEY

OF

MINNESOTA.

THE SEVENTEENTH ANNUAL REPORT.

FOR THE YEAR 1888.

N. H. WINCHELL,
STATE GEOLOGIST.

ST. PAUL, MINN.:
THE PIONEER PRESS COMPANY
1889.

THE GEOLOGICAL

AND

NATURAL HISTORY SURVEY

OF

MINNESOTA.

THE SEVENTEENTH ANNUAL REPORT.

FOR THE YEAR 1888.

N H. WINCHELL,
STATE GEOLOGIST.

ST. PAUL, MINN.:
THE PIONEER PRESS COMPANY
1889.

THE BOARD OF REGENTS

OF THE

UNIVERSITY OF MINNESOTA.

Hon. Greenleaf Clark, St. Paul,	1889
Hon. Cushman K. Davis, St. Paul,	1889
Hon. Knute Nelson, Alexandria,	1890
Hon. John S. Pillsbury, Minneapolis,	1890
Hon. Henry H. Sibley, St. Paul, *president*,	1891
Hon. Gordon E. Cole, Faribault,	1891
Hon. Wm. Liggett, Benson,	1891
Hon. William R. Merriam, St. Paul, the governor of the state,	*ex-officio*
Hon. David L. Kiehle, St. Paul, *recording secretary*, the superintendent of public instruction,	*ex-officio*
Cyrus Northrop, Minneapolis, *corresponding secretary*, the president of the university,	*ex-officio*

TREASURER OF THE UNIVERSITY.

Hon. H. P. Browne, - Address, Commercial Bank, Minneapolis, Minn.

THE BOARD OF REGENTS

OF THE

UNIVERSITY OF MINNESOTA.

Hon. Greenleaf Clark, St. Paul,	1889
Hon. Cushman K. Davis, St. Paul,	1889
Hon. Knute Nelson, Alexandria,	1890
Hon. John S. Pillsbury, Minneapolis,	1890
Hon. Henry H. Sibley, St. Paul, *president,*	1891
Hon. Gordon E. Cole, Faribault,	1891
Hon. Wm. Liggett, Benson,	1891
Hon. William R. Merriam, St. Paul, the governor of the state,	*ex-officio*
Hon. David L. Kiehle, St. Paul, *recording secretary,* the superintendent of public instruction,	*ex-officio*
Cyrus Northrop, Minneapolis, *corresponding secretary,* the president of the university,	*ex-officio*

TREASURER OF THE UNIVERSITY.

Hon. H. P. Browne, - Address, Commercial Bank, Minneapolis, Minn.

CONTENTS.

Page.

Summary statement for 1888 1

Report of N. H. Winchell—

Introduction 5

1. Work done by the Minnesota survey on the crystalline rocks 6
   - (a) Early views. State of knowledge when this investigation was begun 7
   - (b) The problems that were then unsolved touching the stratigraphy of the Azoic 10
   - (c) Publications since the work begun 10
   - (d) The various annual reports; progress from year to year 11
2. The various steps of progress 25
3. The results of the investigation so far as they appear at present. 28
   - The Laurentian age 28
     - Distribution of the Laurentian in Minnesota 29
     - Eruptive syenite 30
   - Age of the Vermilion schists, or "crystalline schists." 31
     - Hornblende schists converted to mica schists 32
     - Nature of the transition from the Laurentian to the Vermilion. 33
     - Effect of hydrothermal fusion 35
   - The Kewatin schists 37
     - Conformable transition from the Vermilion 37
     - Nature of the Kewatin rocks 37
     - Vermilion iron ores 39
     - Origin of jaspilyte 40
     - The Kawishiwin, or greenstone epoch 41
     - Parallels of the Kewatin 42
     - Jaspilyte is in the Kewatin and in the "dioritic group" 45
     - Possibility of rocks younger than the Kewatin before the begining of the Taconic 45
   - The age of the Taconic [Animike, Huronian] 46
     - The opening of the Taconic 47
     - The iron ores of the Taconic 48
     - The Granular Quartz 48
   - The age of the Potsdam 51
     - Equivalent names 51
     - Unconformable on the Taconic 51
     - Further evidence of disturbance during the Potsdam 52
     - Post-gabbro eruptions of the Potsdam age 54
     - Acid eruptions during the Potsdam 55

Page.
- The age of the St. Croix sandstone 56
  - Separateness of the St. Croix and the Potsdam 57
  - Emmons, E. Hitchcock, W. W. Mather, L. Vanuxem, Sir William Logan, James Hall 58-64
- 4. Problems that need further investigation 64
  - Eruptive and sedimentary Laurentian 65
  - Planes of hydrothermal fusion, and their relation to the origin of the crystalline schists 66
  - Date of upheaval of the crystalline schists 68
  - Nature and origin of jaspilyte 68
  - What is the muscovado rock? 68
- 5. Comparison of these results with those reached elsewhere 68

Report of H. V. Winchell.

- Region traversed 77
- Principal varieties of iron ore 79
- Giant's range 81
  - Iron lake 83
  - Westward from Dunka river 85
  - The Giant's range at Hinsdale 88
  - Mallmann's work on the Mesabi range 89

Birch lake region.

- Tonga (or Dunka) river 92
- Other localities around Birch lake 93
- Vicinity of Kawishiwi river 96
- Vicinity of Long lake 97

Lake Superior trip.

- Lake Isabelle 99
- Lake Harriet 101
- Kapokegamak (or Crooked) lake 102
- Gunflint lake 104
  - Gunflint lake to Ogishke-Muncie 106
- Otter Track lake 111
- Lake Vira 115
- Disappointment lake 115
- Round lake 119
- Township 63-9 120
- Prairie River falls 128
- Inferences from the foregoing observations 128
- List of specimens collected by H. V. Winchell, in 1888 135
- Aneroid elevations 144
- Contacts observed 144
- Transitions observed 145
- Conglomeritic structure, where observed 145

Report of Uly S. Grant.

- I. General statement 149
- II. Geological notes 151
- Otter Track lake 151
- Gunflint lake and vicinity 151
  - Sections north of Gunflint lake 152

Page.
- First falls north of Gunflint lake...... 160
- Ogishke-Muncie lake...... 161
- Birch lake...... 162
- Kawishiwi river...... 163
  - In town 63-9...... 163
  - South of Mishiwishiwi lake...... 164
  - The small lake in sec. 32, T. 63-10...... 165
- Lake Isabelle...... 166
- Bellissima lake...... 167
- Pine lake...... 167
- Mayhew lake...... 169
- Iron lake...... 169
- Portage lake...... 170
- Poplar lake...... 171
- Straight lake...... 171
- Caribou lake...... 171
- Meed's lake...... 172
- North Brulé lake...... 173
- Stray lake...... 173
- Gaskanas lake...... 173
- Winchell lake...... 174
- Sham lake...... 176
- Lost lake...... 176
- Brulé lake...... 176
- Lake Georgia...... 178
- Surveyor's lake...... 179
- Found lake...... 179
- Lake Ida Belle...... 180
- From lake Ida Belle to Ogishke-Muncie lake...... 183
  - Narrow lake...... 183
  - Kiskadinna lake...... 183
  - Kiskadinna lake to Round lake...... 183
  - Draper lake...... 184
  - Draper lake to Flying Cloud lake...... 184
  - Flying Cloud lake...... 185
- Shoo-Fly lake...... 186
- Frazer lake...... 187
- Thomas lake...... 189
- Lake Alice...... 190
- Lake Alice to Mishiwishiwi lake...... 191
- Pine Island. Vermilion lake...... 192

III. Summary...... 192
IV. List of, and notes on, typical rocks of each of which 25 specimens were collected...... 193
V. Barometrical elevations...... 200
VI. Catalogue of rock samples to illustrate the foregoing notes...... 201

Museum additions...... 217
Appendix:—List of publications relating to the crystalline rocks...... 231
Index...... 266

ADDRESS.

THE UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, March 31, 1889.

To the President of the University,

DEAR SIR: I have to communicate again an annual report on the progress of the geological and natural history survey of the state, being the seventeenth in consecutive order. Like the last two, this report pertains almost exclusively to the geology of the northeastern part of the state, and is accompanied by some text illustrations.

Respectfully, your obedient servant,
N. H. WINCHELL,
State geologist and curator of the general museum.

REPORT.

I.

SUMMARY STATEMENT FOR 1888.

The work done in the season of 1888 in consequence of the supplementary aid that was rendered the survey by the special appropriation and law of the Legislature of 1887, as mentioned in the last report, will be found reported elsewhere. The explorations for natural gas carried on within the state, whether by private enterprise or by the aid of the special fund, are detailed, with some considerations relative to the general subject of gas in Minnesota, in Bulletin No. 5. The special field-work which was directed, under the same law, to the discovery and definition of the iron-resources of the northeastern part of the state, will be included in this report. But the whole subject in general of the geology of the iron ores of Minnesota will find place in Bulletin No. 6.

There were two parties in the field during the season. One was occupied, in the first part of the season, in making collections of rock-samples from certain typical crystalline formations in typical localities. This was under the direction of Mr. Uly S. Grant. At the same time some new facts were observed. These, with notes made by him later in the season when occupied more specially with the examination of the iron-ore beds, are gathered together by him in a formal report which accompanies this.

The other party was during the whole season at work on the iron-ore beds. This was under the guidance of my son, Mr. Horace V. Winchell, whose report on his work will also be found accompanying this

The work of the season has added materially to our exact knowledge of the geology of the northeastern part of the state, and particularly to that of the nature and relations of the iron ores of the state. A general presentation of this knowledge, in a somewhat systematic manner, has been attempted in this report; but it must be admitted, notwithstanding the time spent on the study, and field-observations that have been recorded, there are still some important, and many less important, questions which the survey cannot answer. But with a consciousness that, however exhaustive the research might be made, there would be questions still unsolved, and that there is a general wish for a full and "final" presentation of the geology of that part of the state so far as present knowledge will yield it, and also feeling that the time has been long that the survey has been going on, and that the working span of one man's life cannot be depended on for indefinite extension, I am constrained to say that we shall enter now upon the preparation of the final report covering the northern part of the state. There will be some supplementary examination to be made, but this will be not very costly, and can be executed while the preparation of the report is in progress.

Volume II of the final report was issued in December, 1888. It is a quarto of about 700 pages, forty-two plates and thirty-two figures, of the same style as Vol. I.

A considerable portion of Vol. III is also ready, and the entire volume will be finished at once. It will contain, along with the paleontology of the strata discussed in Vols. I and II, an account of their systematic relations to the geology of the Northwest. There is also, in readiness for publication, a volume devoted to the birds and mammals of the state, prepared by Dr. P. L. Hatch and Prof. C. L. Herrick. These two volumes should be published at once, in style uniform with those already issued.

The monograph of Messrs. Woodward & Thomas on the microscopic fauna of the Cretaceous, which has been in process of preparation several years, has been completed by those gentlemen and has been transmitted for publication. It will form a chapter in Vol. III. Mr. Ulrich's work on the bryozoa of the Trenton was interrupted unfortunately, when it had proceeded so far as the engraving of the plates, eight having been completed and delivered. This was owing to the exhaustion of the fund for publication by the unexpected cost of Vol. II. Dr. Leo Lesquereux's report on the fossil flora of the Cretaceous in Minnesota, with the accompanying plates, is also intended for Vol. III. It is only an act of reasonable justice to a scientific author that his contributions be published as soon as possible. His rights are not all satisfied by the simple payment of the money involved in his contract to prepare the report. The value of scientific work, especially scientific authorship, is not measured by the manual labor involved in it. So its claims are not satisfied when the material money payment is made. The author expects, and he has a right to demand, that his work shall be published. His researches, so far as they are in new fields, may be covered by later investigators and be announced before his see the light. This reward for scientific authorship, while it cannot be expressed in dollars and cents, and cannot perhaps be included in definite terms in the contract with the author when he undertakes the work of any investigation, yet acts as a powerful stimulant and as a final element in the compensation he reasonably counts upon. He naturally is backward in asserting it; and it is a lamentable fact that credit for some valuable research and some discoveries has been lost to their authors because of the suppression, or at least the tardy publication, of their reports until after others had made the same discoveries and had announced them to the public. In the case of a state survey such delay not only injures the individual but also reflects on the value of the official reports. Wherever scientific facts are first published, there they are forever acknowledged and referred to by future authors. If the state has incurred the cost of an investigation, its chief value is lost if the credit of its discoveries cannot be secured by early publication, and if the same facts are published elsewhere.

The condition of the museum and of the unexamined specimens is about as has been stated in some of the late reports. Not only are the museum halls full to overflowing, but the so-called laboratories of the survey are also full. It has become necessary to deposit the boxes of rock samples in these rooms. All the packing, handling and labeling has been done heretofore in these rooms. Recently, owing to the storage of a large part of the surplus copies of Vols. I and II in these rooms, there has not been room left for doing this work, and it has been transferred to the office, on the second floor of the building.

A record of museum accessions is herewith again reported, the same having been crowded out of the last two reports. Its publication subserves the double purpose of acknowledging donations and of permanence of a record easy to consult in case of desire to find any specimen in the museum, or any information concerning any specimen when once the specimen is in hand. The method of labeling all specimens collected has been found very safe and permanent. It consists of mixing a solution of common shellac, such as can be got of a druggist, with some coloring material and carefully placing the numbers with a small brush or with a stick, on the specimens, by hand. The shellac, being dissolved in alcohol quickly hardens by the evaporation of the alcohol, and embracing the coloring material in the hardened mass, has the quality of permanence of color and insolubility in water. The upper right hand corner of the specimen is used. In case the natural surface is rough, or if the color of the letter to be attached would be so nearly the same as the rock as to render the designation indistinct, the surface is first colored over in a small rectangular spot with some other color of the same kind of material, and when hardened the number is applied over it. The specimens have been numbered as below.

The regular museum series, such as have been placed on exhibition, whether rock-samples, minerals or fossils, have their numbers in *red*, produced by mixing the shellac with "vermilion red."

The series of N. H. Winchell, mainly crystalline rocks, are marked *blue*, produced by mixing indigo with the dissolved shellac.

The series of A. Winchell, also crystalline, are marked *black*, produced by mixing the shellac with india ink.

The samples collected by H. V. Winchell are marked *pink*, a mixture of vermilion red and white lead with the dissolved shellac.

The samples collected and reported by Mr. U. S. Grant are marked *green*, made by mixing the shellac with paris-green.

The specimens in the archæological collection are marked in *white*, mixture of white lead with the dissolved shellac.

The list of museum accessions herewith reported includes only those marked in *red*. All others are listed in connection with the respective field reports.

II.

REPORT OF N. H. WINCHELL.

The crystalline rocks of Minnesota. General report of progress made in the study of their field relations. Statement of problems yet to be solved.

CONTENTS.

Introduction.

1. Work done by the Minnesota survey on the crystalline rocks.
    - (a) Early views. State of knowledge when this investigation was begun.
    - (b) The problems then unsolved.
    - (c) List of publications issued since the Minnesota survey began.
    - (d) The various annual reports.
        - The first annual report, 1872.
        - The second annual report, 1873.
        - The sixth annual report, 1877.
        - The seventh annual report, 1878.
        - The eighth annual report, 1879.
        - The ninth annual report, 1880.
        - The tenth annual report, 1881.
        - The eleventh annual report, 1882.
        - The thirteenth annual report, 1884.
        - The fifteenth annual report, 1886.
        - The sixteenth annual report, 1887.
        - Bulletin No. 2, M. E. Wadsworth, 1886.
2. The various steps of progress.
3. The results of the investigation so far as they appear at present.
4. Comparison of these results with those reached elsewhere.
    - (a) Agreements.
    - (b) Disagreements.
5. Problems still unsolved.

INTRODUCTION. In the course of any investigation that is extended over a number of years, like that of the work of the survey on the crystalline rocks of the state, it is necessary, for an intelligent application of effort, to review the progress made and ascertain as nearly as possible the amount and kind of work that remains. It is one of the characteristics of geological investigation, and particularly of research among the crystalline rocks, that as difficulties disappear, under the reflective scrutiny of the laborer, new problems are presented for solution. In the solution of these more advanced problems the geologist sometimes forgets, in the eagerness of his pursuit, that it is incumbent on him, in the interests of his own work, as well as for the information of others, to render an account of his progress and of his success in surmounting the difficulties that confronted him at the outset. There are but few investigators, in any branch of science, that have not made mistakes. They may have advanced under illusive guides along devious lines, they may have retreated where they ought to have advanced, or advanced where they should have retreated. They have entertained partial or wrong opinions; but it is evident that no one should be held to these errors that are incident to the process. The final statement only ought to stand for the result of the investigation. This may contravene, or it may modify or totally disprove some of the early views. There is hence a justifiable reluctance on the part of an investigator to publish his results till he is satisfied that he is right, and that the work is finished. In the case of the Minnesota survey, however, like all surveys, it ought to be "finished." That is, its work should be rounded out with a so-called completion; for it is evident that however far the work should be continued there would still remain unsettled questions. It is not within the power of one survey, nor of one generation, to exhaust the possible research that might be applied to the examination of the geology of the crystalline rocks.

For these reasons it is thought best to take an inventory of the survey's work and results in the examination of the crystalline rocks of the state. This will be preliminary only, and the apparent truth, as it may be expressed in this report, may appear different in the light of future discoveries, and the final report on this work may be somewhat different from that which is here foreshadowed.

1. WORK DONE BY THE MINNESOTA SURVEY ON THE CRYSTALLINE ROCKS.

The efforts of the survey have been directed, almost wholly, to the field relations of the terranes. It is evident that all laboratory determinations are subordinate, in their bearing on the general geology, to the labor expended in the field. That which is of first importance is a knowledge of the facts as to superposition, transition, and extent of the various kinds of rocks as they exist, in fact. No fine mineralogical disquisitions, or chemical determinations, or stratigraphical suppositions, or historical reviews of past speculations, can bear the weight of a feather in the balance against the facts of field observation. Dr. M. E Wadsworth has truly said* that the field evidence must in all cases be the arbiter and guide to the conclusions of the microscopist in his laboratory work on crystalline rocks, as to their eruptive or sedimentary nature. This supposes that the facts as reported are the actual facts. It is true, however, that from different standpoints the same facts may be reported differently by different observers, or because of a lack of capacity or training in field observation on the part of one or the other.* So far as the work of the survey is concerned, while it would be obviously absurd to assert that no mistakes of field observation have been made, and no incorrect inferences have been arrived at by the field observers, it is no more than the facts of the case will justify to say that the Minnesota survey has devoted more time and accumulated more exact knowledge regarding the field-relations of the crystalline rocks than has any other state survey; and probably has given more time to field work in the crystalline rocks of the Northwest than the United States geological survey. In some instances extensive routes of observation have been gone over more than once for correction or verification. These field observations have been reported in whole or in part, from time to time chronologically in the reports of progress, but their fragmentary parts have not been grouped and presented systematically so as to show the results as they appear in the mind of the writer.

---

* Notes on the geology of the iron and copper districts of Lake Superior, p. 74.

(a) *Early views. State of knowledge when this investigation was begun.*

When the Minnesota survey was begun, in the fall of 1872, there had been but little done on the crystalline rocks of the Northwest. In addition to the desultory and often fragmentary work of the Canadian survey, which should be classed rather as exploration and sketch-mapping, and which had been spread over the Canadian shores of lake Superior as far as to Pigeon river by Mr. Robert Bell, the only published information respecting the older terranes in Minnesota was in the reports of Keating, Allen and Schoolcraft, Shumard, Norwood, Whittlesey and Hall, with some brief notes by Bigsby, on the Lake of the Woods. Douglas Houghton had also visited Grand Portage and some points further west. Eames & Hanchett had also rendered short reports on some features of the northern part of the state.† There had been published also, in 1871, in the *Zeitschrift d. Deutschen*

---

* Compare Irving's and Wadsworth's different observations on the "Eastern Sandstone," *Copper-bearing rocks of lake Superior*, Monograph No. 5, U. S. Geol. Survey, p. 356, et seq.

†See Vol. I. final report, for some account of these early publications.

geologischen Gesellschaft, a paper by Dr. J. Kloos giving some notes on Minnesota, in which important new observations were recorded. It was two or three years later, however, that this last paper was first known to the writer.* Prof A. Winchell and Prof. R. D. Irving had also made some observations on the geology of the Northwest, particularly in Michigan and Wisconsin. The report of Foster and Whitney on the copper and iron districts of the lake Superior region makes no mention of the geology of Minnesota further than the reported occurrence of one or two minerals on the north shore of lake Superior.

So far as any of this work touches the geology of Minnesota, in the areas of the crystalline rocks, it may be divided into two classes.

1. That which is descriptive of the geographic extent of the crystalline rocks.

2. That which by careful mineralogical determinations discriminates the rock species from each other, or classifies the formations stratigraphically.

In the former may be placed the reports of Keating, Allen, Schoolcraft, Shumard, Eames, Hanchett and Houghton; in the latter are the reports of Norwood, Whittlesey, Hall and Kloos. Norwood's report partakes largely in the character of the first group. Whittlesey's was the result of observations made in company with Norwood, and embraces about the same facts and conclusions. Prof. James Hall's report of a trip from St. Paul to lake Shetek † in 1866, embraces the first reference of any of the crystalline rocks of the state to their supposed stratigraphic equivalents in the eastern states and Canada. He distinctly refers the gneisses at Redwood Falls to the *Laurentian,* and the quartzytes at New Ulm and Pipestone to the *Huronian,* names which had been adopted by the Canadian geologists, though with some ambiguity and overlapping of description, the former in 1854, § and the latter in 1857, §§

---

* See transalation of this in the tenth anual report.

† 1866, Trans. Am. Phil. Soc., Philadelphia, p. 329.

§ Geol. Report Can. Survey, 1857, p. 7. The name was used in "Sketch of the Geology of Canada," printed in French in Paris, 1855. This is embraced in "Canada at the Universal Exposition of 1855," by J. C. Tache, a report printed at Toronto, "by order of the Legislative Assembly," 1856. It was first announced in the report of the survey for 1852–53, which, however, was not published till 1854, at Quebec.

§§ In Mr. Murray's reports for 1853, 1854, 1855 and 1856 the terms "Huronian system" and "Laurentian system" are used incidentally, and as headings to chapters; but as these were not offered for publication by Mr. Logan till March, 1857, they cannot be considered as official announcements of those names till the date of their actual publication.

Just prior to the adoption of these terms, expressive of a distributive chronological classification of the terranes of the crystalline rocks, at least all those lying below the Potsdam sandstone, Messrs. Foster and Whitney[*] had employed the term *Azoic*, after Murchison and Verneuil,[†] and had divided them mineralogically rather than chronologically, into gneiss, mica and hornblende slate, chlorite, talcose and argillaceous slate, quartz and marble.[‡] They considered them an indivisible complex series, whose foldings and metamorphic changes rendered a determination of their original stratigraphic order impossible. This term, with its significance as interpreted by Foster and Whitney, was adopted by Dana in the first and second editions of his Manual of Geology (1862 and 1864), and by the Vermont geologists in 1862 (Geol. of Vermont, Vol. I). It was not till 1874 when the third edition of this manual was issued (by some mistake also called "second" edition), that the terms used by the Canadian geologists were adopted in this work. They are continued in the fourth ("third") edition issued in 1879. Dr. Ebenezer Emmons evidently shared the views of Foster and Whitney. Aside from his opinion that the Huronian of Canada was only a synonym of his Taconic which he insisted was not "Primary," he divided the "primary" rocks into two groups,[||] based on the varying theoretical agency of heat in their production and present condition, viz., *pyro-crystalline* and *pyro-plastic.* In the former, in the main, he embraced granite, gneiss, mica slate, talcose slate, hornblendic and hypersthene rocks, that is to say, speaking broadly, the acid eruptive rocks and their accompanying schists, and in the latter he included the most of the basic eruptives.[§]

When the Minnesota survey began [1872] the Wisconsin survey, lately completed by Chamberlin, had not yet been instituted.[§§] and the Michigan survey, revived in 1869, did not present its first final volume for publication till May 1, 1873. The writer, having been at work in 1870 on the Michigan survey, was, however, acquainted with the views of the director, Prof. A. Winchell, and of major T. B. Brooks, the geologist of the iron regions, touching the equivalency of the Marquette iron formation to the Huronian of Canada, as subsequently announced in Volume I of that report.

---

[*] Proc. A. A. A. S. 1851, p. 4.

[†] The Geology of Russia in Europe, Vol. I, p. 10.

[‡] Report on the Geology of the lake Superior land district; part II. p. 2. Am. Jour. Sci., (2) xxiii. 305.

[||] Manual of Geology, Second edition, 1860, p. 52.

[§] Emmons also regarded some limestones as pyro-crystalline, and he embraces it in both series of that class of rocks. Op. cit. p. 60 et 66.

[§§] The law ordering the Wisconsin survey was approved March 18, 1873.

The first volume of the New Hampshire report by Prof. C. H. Hitchcock was issued in 1874, and that devoted to the stratigraphic geology of the Archæan in that state in 1877.

(b) *The problems, therefore, that were then unsolved*, touching the stratigraphy of the Azoic or Archæan, were as follows:

1. Could the Azoic be divided stratigraphically with any probable general applicability?
2. Could the terms Huronian and Laurentian, as employed by the Canadian geologists, find any equivalents in the crystalline rocks of Minnesota?
3. What relation did the Huronian bear to the Cambrian?
4. What relation did the Huronian bear to the Taconic?
5. What relation did the Cambrian bear to the Taconic?
6. What relation did the Animikie bear to the Taconic, the Cambrian and the Huronian?

Correlatively with these problems appeared others, although they did not present themselves so forcibly till some time later, viz.:

7. Could the rocks classed as Laurentian be distinctly shown to be of older date than the Huronian? All of them, or a part of them?
8. Could the Laurentian be subdivided?
9. Is the Laurentian derived from originally sedimentary rock? or from primarily eruptive rock?
10. If originally sedimentary, or if primarily eruptive, why is it mainly an "acid" rock?

(c) *Publications issued since the work began.*

In an appendix is a list of publications that have been issued since 1872, bearing on the geology of the crystalline rock, of the Northwest, so far as the writer has learned of them. It is probably not complete, but certainly embraces everything that has contributed to the subject any important information. To all of these the writer must acknowledge great indebtedness, and to none greater than to the geologists of Michigan and Wisconsin, Maj. T. B. Brooks, Dr. A. Winchell, Prof. R. Pumpelly, Dr. C.

Rominger, Prof. C. E. Wright, A. R. Marvine, Prof. R. D. Irving, Prof. (now President) T. C. Chamberlin, E. T. Sweet, and to Prof. M. E. Wadsworth, now state geologist of Michigan.

(d) *The various annual reports: progress from year to year.*

That there has been some advance in the science of the crystalline rocks in America at large as well as in those of the Northwest, and of Minnesota specifically, since 1872, is evident from a comparison of the problems unsolved in 1872 with those that are presented to the geologist in 1889; and while this advance is mainly due, of course, to the labor of the authors whose works are listed above, some of the steps of this progress may be accredited to the Minnesota survey. Some of these steps, due to a large extent, or wholly, to the Minnesota survey, it will be appropriate here to enumerate. There may be still a difference of opinion among the geologists of the United States and Canada as to what constitutes a step of progress, and as to who should be regarded as its author. But it is the design of the writer to mention only those steps which appear to his judgment to be actual advances, whether they appear so to others or not, and in that he holds no one responsible but himself. As to the responsibility and the credit for these steps, that is decided, as in all similar cases in science, by the dates of the published literature that announces them. The record, therefore, which will here be given, will be that of the progress, mainly, of the writer's own mind and apprehension of what he considers successive advances.

The first annual report, 1872.

The first annual report was made before any time had been allowed for examination of the crystalline rocks of the state by the present survey. Therefore the only design was to express concisely the state of knowledge that then was available, so far as it bore on any classification that might be accepted. The views of Foster and Whitney as expressed in 1851,[*] grouping the crystalline rocks in the same manner as Murchison and Verneuil, all in one system under the name Azoic,[**] were cited and their table of stratification was quoted. At the same time the subdivision into Laurentian and Huronian, introduced by Logan and Hunt ever, acquainted with the views of the director, Prof. A. Winchell, and of major T. B. Brooks, the geologist of the iron regions, touching the equivalency of the Marquette iron formation to the Huronian of Canada, as subsequently announced in Volume I of that report.

---

[*] *Report on the Geology of the lake Superior land district.* Part II, p. 8. *Proc. A. A. A. S.* 1851, p. 4

[**] Geology of Russia, Vol. I, p. 10.

The first volume of the New Hampshire report by Prof. C. H. Hitchcock was issued in 1874, and that devoted to the stratigraphic geology of the Archæan in that state in 1877.

(b) *The problems, therefore, that were then unsolved*, touching the stratigraphy of the Azoic or Archæan, were as follows:

1. Could the Azoic be divided stratigraphically with any probable general applicability?

2. Could the terms Huronian and Laurentian, as employed by the Canadian geologists, find any equivalents in the crystalline rocks of Minnesota?

3. What relation did the Huronian bear to the Cambrian?

4. What relation did the Huronian bear to the Taconic?

5. What relation did the Cambrian bear to the Taconic?

6. What relation did the Animikie bear to the Taconic, the Cambrian and the Huronian?

Correlatively with these problems appeared others, although they did not present themselves so forcibly till some time later, viz.:

7. Could the rocks classed as Laurentian be distinctly shown to be of older date than the Huronian? All of them, or a part of them?

8. Could the Laurentian be subdivided?

9. Is the Laurentian derived from originally sedimentary rock? or from primarily eruptive rock?

10. If originally sedimentary, or if primarily eruptive, why is it mainly an "acid" rock?

(c) *Publications issued since the work began.*

In an appendix is a list of publications that have been issued since 1872, bearing on the geology of the crystalline rock, of the Northwest, so far as the writer has learned of them. It is probably not complete, but certainly embraces everything that has contributed to the subject any important information. To all of these the writer must acknowledge great indebtedness, and to none greater than to the geologists of Michigan and Wisconsin, Maj. T. B. Brooks, Dr. A. Winchell, Prof. R. Pumpelly, Dr. C.

Rominger, Prof. C. E. Wright, A. R. Marvine, Prof. R. D. Irving, Prof. (now President) T. C. Chamberlin, E. T. Sweet, and to Prof. M. E. Wadsworth, now state geologist of Michigan.

(d) *The various annual reports: progress from year to year.*

That there has been some advance in the science of the crystalline rocks in America at large as well as in those of the Northwest, and of Minnesota specifically, since 1872, is evident from a comparison of the problems unsolved in 1872 with those that are presented to the geologist in 1889; and while this advance is mainly due, of course, to the labor of the authors whose works are listed above, some of the steps of this progress may be accredited to the Minnesota survey. Some of these steps, due to a large extent, or wholly, to the Minnesota survey, it will be appropriate here to enumerate. There may be still a difference of opinion among the geologists of the United States and Canada as to what constitutes a step of progress, and as to who should be regarded as its author. But it is the design of the writer to mention only those steps which appear to his judgment to be actual advances, whether they appear so to others or not, and in that he holds no one responsible but himself. As to the responsibility and the credit for these steps, that is decided, as in all similar cases in science, by the dates of the published literature that announces them. The record, therefore, which will here be given, will be that of the progress, mainly, of the writer's own mind and apprehension of what he considers successive advances.

The first annual report, 1872.

The first annual report was made before any time had been allowed for examination of the crystalline rocks of the state by the present survey. Therefore the only design was to express concisely the state of knowledge that then was available, so far as it bore on any classification that might be accepted. The views of Foster and Whitney as expressed in 1851,* grouping the crystalline rocks in the same manner as Murchison and Verneuil, all in one system under the name Azoic,** were cited and their table of stratification was quoted. At the same time the subdivision into Laurentian and Huronian, introduced by Logan and Hunt

---

Report on the Geology of the lake Superior land district. Part II, p. 8. *Proc. A. A. A. S.* 1851, p. 4

** Geology of Russia, Vol. I, p. 10.

of the Canadian survey, though contested by Prof. Whitney, was generally prevalent, and these terms were included in the brief description then published of their extension into Minnesota.

The most important question, however, which was considered in the first report, bearing on the classification of the Laurentian and Huronian, was that pertaining to the *Potsdam sandstone.* The bearing of this discussion, however, upon that classification was not fully apprehended, as its application and significance have been brought to light in some of the later years of the survey. Drs. Owen and Norwood, as well as A. Winchell * considered the red sandstones and quartzytes of Wisconsin and Minnesota as the conformable downward extension of the light-colored sandstones of the St. Croix and Mississippi valleys which they parallelized with the Potsdam of New York. It was just before the commencement of the Minnesota survey (Feb., 1872, Am. Jour. Sci., p. 93), that Prof. R. D. Irving demonstrated conclusively that at Baraboo, Wisconsin, there was a marked unconformity between the red and the light-colored sandstones, and that they could not belong to the same system. Prof. Irving coincided with Prof. James Hall,** who had previously regarded the light-colored upper sandstones as Potsdam and had been followed by nearly all geologists of America, in referring the lower quartzytes to the Huronian of Canada.

The first report of the Minnesota survey refers the lower quartzytes to the Potsdam horizon of New York and gives the name *St. Croix* to the overlying light-colored sandstones. In the light of all subsequent examinations, both east and west, there has appeared nothing that has disproved the correctness of this reference, but on the other hand every fact, whether of paleontology or of stratigraphy, which has been brought out since 1872, relating to this horizon, has been in accord with it. It must not, however, be considered as sufficiently demonstrated, so long as there are competent dissentients who still restrict the name Potsdam to the later sandstones. It will appear later in what way this bears on the classification of the rocks styled Azoic by Messrs. Foster and Whitney and later Archæan by Prof. J. D. Dana.

---

* Owen's report on Wis., Iowa and Minn., pp. 48, 187, and Table, p. 634. Am. Jour. Sci. (II) xxxxii. 226, 1864.

** Report of progress to the Governor of Wisconsin, 1860; also Notes upon the geology of some portions of Minnesota from St. Paul to the western part of the state, *Trans. Am. Phil. Soc.* Philadelphia, June, 1866.

The second annual report, 1873.

In the second report was an account of the geology of the Minnesota valley. While this entered into a somewhat detailed description of the field appearances of numerous outcrops of the crystalline rocks between New Ulm and Big Stone lake, there was no attempt made to classify them, or to refer them to any horizon of rocks exposed in the northern part of the state. They were regarded as a southern extension from the granites in the northern part of the state, and were presumed to have their parallelisms there if they could be referred to their proper places. The red quartzyte at (or near) New Ulm is again referred to the age of the Potsdam.

The sixth annual report, 1877.

The report contains the first recorded observations made by the Minnesota survey on the crystalline rocks of the northeastern part of the state. They were made at Northern Pacific Junction and about Little Falls, on the Mississippi river. An examination was also made of the granitic rock in the vicinity of Motley. These notes are simply descriptive, without any effort at classification.

In this report is a description of the geology of Rock and Pipestone counties, in which are large outcrops of the same red quartzyte as seen at New Ulm, and at Baraboo, Wisconsin. It is classed as Potsdam.

The seventh annual report, 1878.

In the seventh report is a sketch of a somewhat extended systematic examination of the mining geology of the northeastern part of the state. The coast of lake Superior was examined from Duluth to Pigeon point, a trip was made overland from Grand Portage along the international boundary to Basswood (or Basimenan) lake, thence to Vermilion lake, the St. Louis river, across to the Mississippi and down that river to Little Falls. Some examination was also made of the country between Pigeon point and the Brule river by ascending some of the valleys from the shore of lake Superior. Among the geological results of the season's field work, as stated in the report, on p. 10, are the following points which may be classed as advances in classification of the crystalline rocks of the state.

1. The syenites, granites and other rocks that had been named

Laurentian by the Canadian geologists graduate conformably into the schists and slates that had been named Huronian by the same—as designated and defined by Mr. Robert Bell. This is also stated by Mr. Bell in his report for the Canadian geological survey, 1873.* This definition, however, of the Huronian formation, as will appear later in this summary, was incorrect, and the correction was made by Mr. A. C. Lawson who named the schists *Keewatin series.*

2. The gray quartzyte formation, No. 4 of the seventh report, is the iron-ore formation of the Mesabi range and graduates conformably into siliceous iron-charged rock, "which in some places furnishes a valuable iron ore in large quantities."

3. The Cupriferous formations, later known as the Kewenian, or Keweenawan, lies unconformably over several formations, and is interstratified with the beds of the latest.

The evidences of these conclusions are not given in this report. The detailed observations have not yet been published, but a synopsis of them was published in connection with a preliminary description of rock samples collected, in the ninth annual report.

The eighth annual report, 1879.

So far as the eighth report records the work of 1879 on the crystalline rocks, it embraces the descriptive account of the outcrops in the Minnesota valley by Mr. Warren Upham, and some mineralogical notes on the eruptive ranges of the lake Superior region by Prof. C. W. Hall. The observations of the writer in the northwestern part of the state, in 1879, have never been published in full, but a synopsis of them was published in connection with a preliminary description of rock samples collected, in the tenth annual report.

In a preliminary chapter are some mineralogical notes on the "Cupriferous series at Duluth" (p. 22). In this a distinction is drawn between the labradorite rock, or "gabbro," and the red orthoclastic syenite which is mingled irregularly with it, the latter being regarded as the result of local fusion of some of the sedimentary strata, probably some of the strata of the Cupriferous series. The whole trap and Cupriferous series of lake Superior is here assigned to the age of the Potsdam sandstone.

---

*Report of progress, 1872-3, p. 106.

The Ninth annual report, 1880.

This report gives a preliminary description of 442 rock samples collected in the region of the crystalline rocks northwest from lake Superior, in 1878, with a running brief commentary on their field relations. It contains but little attempt at classification of the stratigraphy. A distinction of unconformity is made on p. 82 between the gray slates and quartzytes of the south side of Gunflint lake and the hydromicaceous rocks of the north side, the two being separated by a conglomerate-breccia, and the more northern rocks being regarded as the equivalent of what the Canadian geologists had styled Huronian. This conception of the Canadian Huronian was derived from Dr. Hunt's having described the Huronian as in the main a mass of greenstones, and Dr. Bell's report on the region westward from Thunder bay in 1872. Observations are recorded on p. 94 indicating a conformable passage from what was then regarded as Huronian to the lower syenites, or Laurentian.

The tenth annual report, 1881.

The preliminary description of rock-samples is continued in this report, embracing those collected in 1879, and extending the list to No. 836 inclusive. There is also a renewed discussion of the Potsdam sandstone and its western equivalents, and a short description of some typical thin sections of the rocks of the Cupriferous, or Kewenawan, in Minnesota.

This report embraces some attempt at partial classification, stratigraphically, of the crystalline rocks.* The strata that comprise the island at Grand Portage bay are described in detail, with references to the rock-samples illustrating them. This is followed by a "Generalized section of the alternating beds of the formation," and of the Animikie (Taconic) and lower terranes to the granites and syenites of the region north of Gunflint lake. It is as follows:

Generalized section at Grand Portage and northwestward to Gunflint lake.

1.	The Palisade rock, or the "red rock."	
2.	Green shales, etc., in the bay east of Red point (Nos. 232, 235 and 239).	
3.	Layer of trap, like 540 (542) seen	14 feet.
4.	Chalcedonic amygdaloid (543) seen	20 feet.

---

*See pp. 47, 49, 87, 94, 112, 123-136.

5.	Fibrous green trap striking E. and W. through the island and forming its highest parts. In spots it is globuliferous with hard, dark, strong, shot-like pellets about ¼ inch in diameter, (Nos. 544 and 545)	35 feet.
6.	Even-grained sandrock (546) seen	8 feet.
7.	Trap bed, finely and irregularly jointed, with nodules of white saccharoidal calcite (547) seen	36 feet.
8.	Quartzyte (548) seen	5 feet.
9.	Conglomerate (549) seen	16 feet.
10.	The rock No. 540, forming the great trap covering of the quartzyte hills at Grand Portage; seen 50 ft.; estimated	250 feet.
11.	The slate and quartzyte terranes seen in the hills at Grand Portage, generally, and along the international boundary as far west as the west end of Gunflint lake, estimated	400 feet.
12.	Jasper and iron-ore beds of the Mesabi, and southeast of Vermilion lake.	
13.	The micaceous and chloritic schists and slates of Vermilion lake and the dalles of the St. Louis river.	
14.	The mica schists, granites and syenites of the region north of Gunflint lake.	

This takes no account of the great labradorite range, which in some places forms the Mesabi, nor of the iron-ore deposits of Mayhew lake, because these are apparently included in the rock Nos. 258 and 540, or in an immense outflow of molten matter at a date somewhat earlier (V. No. 695 and 816). Nor does it mention the conglomerate at Ogishke Muncie lake, because that is apparently an incident of the slaty and talcose beds included in sub-No. 13; nor the red granite of the region of Brulé Mt., because they are probably a modified condition of the Palisade rock.

Respecting the parallels of the quartzyte strata composing a part of Isle Royal, so far as found in Minnesota, the following statement is found on page 49.

Its dip, color and bedding recall the red quartzyte in S. W. Minnesota, but it is rather less siliceous than that. In the same manner, however, it overlies a coarse pebbly conglomerate, which in the same way indicates its relation to the red quartzyte of Grand Portage island and of Pigeon Point peninsula (No. 290), as well as to the sandrock and shales of Fond du Lac.

Not at that time having realized the fact of the existence of two hematite iron-ore horizons, in two separate and unconformable formations, there are some intimations of the confusion of stratigraphic interpretations which the writer discovered when the effort at general classification was undertaken. Thus, on page 94,—

The "Gunflint beds" (i.e., the jasperoid beds) south of Gunflint lake (see after No. 747) have been associated with the slates and quartzytes of the overlying formation (i. e., the Animike) rather than with the talcose, slaty beds underlying (see 426), but observations about Town Line and Ogishke Muncie lakes seem to indicate that they are here a part of a schistose, slaty formation, highly inclined, which belongs to the Huronian (i. e., as the Huronian had been described in the region) passing into the great conglomerate of Ogishke Muncie lake."

At the same time the conglomerate about Ogishke Muncie lake was regarded as a single formation, and, while in all descriptions and sections that had been given, it had, as a totality, been grouped as a part of a terrane separate from the Animike, yet there were stated to be some considerations that seem to require it to be considered a part of the Animike (p. 95); and that the horizontal slates (the Animike) as a whole may also pass into the tilted slates as a whole. It will only be necessary to state that this latter idea was one of the errors that are inseparable from the progress of any such investigation. It was recorded at the time as expressive of the stage of interpretation of the facts that had then been reached. Yet it was not wholly erroneous. The facts appealed to, conflicting as they appeared then, are facts still, and they go with numerous other observations to force the abandonment of the idea that the Animike is convertible into the "talcose" or sericitic slates and schists of the region further west, although they do become highly tilted. The former idea, however, when separated from the latter, and supplemented by further statement in harmony with a wider field of observation, has stood the test of all the study and observation that have been devoted to this point, and may be considered as a step of progress, *viz.*, The formation of horizontal slates of the vicinity of Gunflint lake and the international boundary is the same as the highly tilted slate and quartzyte formation that passes into the slaty conglomerate of the region of Ogishke Muncie lake.*

In regard to the epoch of the great outflow of the labradorite rock, the "gabbro," some general statements are given on pages 112 and 113, based on observations at Beaver Bay, which show that this rock preceded the advent of the bulk of the eruptive traps of the Cupriferous. The conclusions are in these words:

---

* Prof. Irving and the Wisconsin and Michigan geologists, as well as all the Canadian geologists except Dr. A. C. Lawson, so far as known, regard these horizontal slates when broken and tilted and the tilted schists as both included in the Huronian; and Prof. Irving has referred to this hypothetical conversion of one to the other in support of that view. (Copper-bearing rocks of lake Superior, Mon. V., U. S. Geol. Sur., p. 443.)

(1) The Great Palisades are of a rock, the equivalent, geologically, of the slaty quartzyte (Nos. 127 and 528) at Beaver Bay, and below that point; and to the red syenite of the islands below Beaver Bay, and of the west bluff of Beaver bay; and to the red (often quartzless) rock associated with the gabbro at Duluth. These beds also constitute the red bluffs at Tischer's near Duluth, and New London, as well as the red rocks at Baptism river and the East Palisades.

* * * * * * * * * *

(2) The feldspar masses are of the same rock (geologically) as the Rice Point gabbro, and both are the result of copious, and perhaps one of the earliest, igneous outflows of the Cupriferous. * * * The late outflows derived fragments from the "clinker fields" and from the knobs of feldspar already formed, as they passed along; and when these had been covered by later sedimentation such sedimentary beds were also involved in the later upheavals and fusions.

The "slaty quartzyte" here mentioned as the probable equivalent of the Palisade rock, is a firm, purplish felsyte containing some angular quartz grains.

In the discussion of the question—what are the western equivalents of the Potsdam sandstone—the tenth annual report records some departures from the conclusions of the Wisconsin geologists, and reverts to the opinions expressed in the first annual report, to the effect that the Potsdam sandstone of New York is not found at all in the bluffs of the Mississippi river, but that it is more likely to be represented by the red sandstone and shales that constitute, with the associated eruptive rocks and conglomerates, the Cupriferous or Kewenawan formation of lake Superior. It maintains that the Taconic system was established correctly by Dr. Emmons, and that it is repeated in the Animike of Thunder bay, as well as in the Georgia group of Vermont. This last is an important step of progress, in the opinion of the writer, and one that no later discoveries have tended to invalidate. This conclusion was reached by a comparison of the described stratigraphy and the paleontology of the formations involved in the east, with those of the west. The Potsdam sandstone, or quartzyte, in both places lies probably unconformably over the Taconic.

The eleventh annual report, 1882,

While containing some matter relating to the mineralogy and lithology of the state, also embraces a table of the systematic geology of the crystalline rocks. This represents the "Huronian" as extending from the Potsdam formation through the

Taconic, also embracing the formation since named Keewatin by Dr. A. C. Lawson, and the mica schists since named (in the report for 1886) Vermilion group[*] by this survey. The black slates and the quartzytes of the Animike and the Ogishke Conglomerate are made the equivalent of some of the Taconic. This includes also the iron-bearing rocks of the Mesabi range and Vermilion lake, the "Gunflint" beds and the slates and quartzytes at Thomson. The magnesian sericitic schists of the region of Vermilion lake and north of Gunflint lake, while placed below the Taconic and above the mica schists (which are styled "Montalban?") are doubtfully supposed to represent the true Huronian.

Prof. A. H. Chester, in this report, parallelizes the iron districts of Minnesota, i. e., the Mesabi and the Vermilion ranges, both with the "Huronian," and specially dwells on the resemblance of the Mesabi iron-bearing rocks to those of the Penokee range in Wisconsin. He also calls special attention to the close geological similarity between the Vermilion iron deposits and those of Marquette.

The thirteenth annual report, 1883.

In this report is found the first statement that indicates the necessity of separating the Vermilion ore horizon from the Mesabi ore horizon. See pp. 24, 37. It is here assigned to the formation of "Huronian conglomerates and greenstones" (see Fig. 5, p. 22), the same that in the eleventh report was described (p. 170) as "magnesian, greenish, soft schists, becoming syenitic and porphyritic; seen on the north side of Gunflint lake, along the international boundary at Basswood lake, and at Vermilion lake," the formation of graywackes and sericitic schists which has since been designated Keewatin, the same that in the ninth report was said to be unconformably under the Animike at Gunflint lake.

This report also describes primordial fossils from the red quartzyte of southwestern Minnesota, the same that Prof. James Hall had classed as Huronian, and that had been also regarded Huronian by the Wisconsin geologists. These fossils are *Lingula calumet* and *Paradoxides barberi*, and the beds containing them are supposed to be represented in the lake Superior region by the red quartzyte at the head of Wauswaugoning bay and on

---

[*] About the same time the Vermilion group was named *Coutchiching* by Dr. Lawson. Am. Jour. Sci. (3) xxxiii., p. 478.

Pigeon point, which in the tenth report was supposed to be extended to Isle Royal.

The fifteenth annual report, 1886.

A large amount of field-work was done in 1886. It added much to the evidences of the correctness of the general parallelisms that had been gradually wrought out by the survey. It also introduced some new problems, and showed the necessity of instituting some subordinate divisions in the formations that had been spoken of in other reports. It also showed the necessity of abandoning some of the hypothetical parallelizations that had been entertained.

In respect to the gabbro formation, the Mesabi overflow, it was found to be indistinctly separable from another, and earlier, eruptive rock which constitutes a prime feature in the topography, and which occupies a wide belt of country running along north of the gabbro area, its line of direction being rudely parallel with the north limit of the gabbro. A general representation of the geographic areas of the various formations was attempted on a colored geological map of the northeastern part of the state. The gabbro was found to have extended so far north as to have covered from sight the line of strike of the Animike (p. 381) and to have come into contact with the older syenite (pp. 347–49). It was intimated that the Animike formation overlay one eruptive rock and underlay the other, and that it seemed to embrace the Ogishke Muncie conglomerate in its lower portion (p. 381). The entire eruptive rock was found to be in some places a remarkable agglomerate, and in various ways to become changed to greenish schists, chloritic and sericitic, and to embrace in its mass, generally in a manner of unconformity, the jaspilyte and iron-ore of the Vermilion lake region. At the same time this green rock exhibited at times very manifestly some signs of aqueous stratification; at other times no such structure could be found in it, and it merged into a dense, homogeneous, massive doleryte. The graywackes which are in this greenstone formation, fade out by merging into its evidently eruptive condition, but in many places are purely sedimentary, having much quartz as rounded grains and pebbles, arranged in sedimentary layers.

The mica-schist belt which was shown to be stratigraphically below the graywacke-greenstone horizon was named *Vermilion* group, or series. It was said to merge into the gneisses below sometimes conformably and at others to be united with them through a series of mutually intersecting dikes, the gneissic rock penetrating the schists, in their original condition, probably of a basic eruptive, and the latter also cutting the contiguous gneissic masses. These rocks are both also cut by basic dikes of later origin (pp. 290–296).

The lowest rock seen was described as gneiss; but at the same time the gneissic structure was found to not always prevail. This lowest rock, which was accepted as Laurentian, is not only sometimes massive, but it is either granite or syenite, i. e. the dark mineral is sometimes mica and sometimes hornblende, or both at the same time.

The granites and syenites were not all put into the same stratigraphic horizon. The "fundamental gneiss," which manifestly lay below the mica-schist horizon, occupies a distinctly marked stratigraphic place. Such is that seen at the northwest end of Vermilion lake. Not to mention the red syenite which is intimately associated with the gabbro, and is certainly of the same date, in its present condition, as the gabbro, a further distinction was introduced by which the rock of the Giant's range, where the range consists of a narrow and abrupt ridge of granite rock, is separated from the age of the Laurentian, and is shown to be the result of local change in some bedded sediments probably later than the Laurentian — a change that, beginning with a partial crystallization of the beds *in situ* by which fine-grained, red-weathering syenite, not distinctly individualized as to its mineral constituents, was produced, and continued, under the action of the same dynamic forces, whatever they are, till a perfect fusion and subsequent extrusion and re-crystallization of the same matter were enacted. This was discussed and roughly illustrated on pp. 347 and 349. Some of the distinct observations are recorded on pp. 352 and 353. The cause of this fusion of the sedimentaries was supposed to be the great eruptive epoch of the gabbro; and this red syenite is made the parallel of the "red rock" of the earlier reports, the red quartz porphyry and the "palisade rock" of the lake Superior shore. The gabbro is not present, however, in all places where this fusion has resulted in extrusion of the acid molten rock, although it is nearly adjacent, or actually overlies the acid rock in many places. In the report this change in the ancient sediments is attributed to the contact of the molten gabbro on them, but there may be and probably are, many places where the extruded acid rock came from some greater depth, though yet within the super-crust, and its fusion and extrusion may not be attributed to immediate effect of contacting gabbro, but must be supposed to be only a part of a widespread and deep-seated metamorphic action that affected the region and culminated in extruded molten rock only along those lines where the dynamic action was most intense. Such a line of intense activity seems to be marked by the location of the narrow ridge known as the Giant's range, at least south and southwestward from Birch lake.

The sixteenth report, 1887.

The results of systematic stratigraphy contained in the sixteenth report, while varying somewhat from those of the fifteenth, in the main are concordant therewith. They were drawn from a special reconnoissance of the region of the typical Huronian, north of lake Huron, and a comparison of the results of that reconnoissance with a re-examination of the so-called Huronian of the Marquette and Gogebic iron regions of Michigan, united with previous knowledge of the region of northeastern Minnesota. In some of these results my brother and myself are not quite in concord, but these differences appertain solely to the possible parallelisms of some Michigan and Wisconsin formations with some in northern Minnesota, and on making further field examinations and research into the comparative lithology they may disappear entirely. In the following summary only those systematic results that are in harmony with the writer's convictions are stated, with some foot-notes that call attention to interpretations that are entertained by my brother.

The name Huronian, if used at all, should be applied only to the strata that were first included under the term when it was introduced and defined, and to their stratigraphic equivalents in other parts of the country. The English geologists do not recognize the formation in the British Isles, but include the strata that are presumably included under this term by the Canadian geologists, in the term Lower Cambrian, which embraces the Primordial fauna. The definition of the Huronian which has been accepted is that of Logan, based mainly on the observations of Murray in the region north of lake Huron, republished in the "Geology of Canada," 1863.* With this understanding the sixteenth report shows an effort to trace the original Huronian formation through Michigan and Wisconsin to Minnesota, and to ascertain the Minnesota equivalents of some of the minor divisions of the crystalline rocks older than the Huronian.

---

*It is well known that the Canadian geologists have later extended the term widely beyond its typical region, and amplified its significance, so as to make it cover all the schists down to the gneisses of the Laurentian. Recently, however, Dr. A. C. Lawson has separated these schists from the proper Huronian, and has designated a part of them Keewatin. "Report on the geology of the lake of the Woods region." An. Rep. 1885, Can. Sur.

The Huronian, in its typical locality, embraces three principal members.

1. Red and white quartzyte, granular and sometimes conglomeritic.
2. Slate and gray quartzyte, sometimes conglomeritic, making a conglomeritic slate, or "slate conglomerate."
3. Very fine-grained gray or white quartzyte.

These are fragmental, and show every character that is known to indicate sedimentary origin. The formation embraces no mica-hornblendic schists, no sericitic schists, no typical graywackes, no gneiss or gneissic rock. The beds dip with uniformity toward the south, are cut by doleritic intrusions and are overlain by the products of such eruption. They lie unconformably on a "gneiss" which is admitted to belong to the Laurentian, from which the formation received many and conspicuous boulders. The thickness of the formation may be as great as ten thousand feet. There is considerable evidence to show that the upper quartzyte lies unconformably on the slates and slaty conglomerate, although there was no actual observation of such a relation. The formation also embraces red felsytes and some gray gabbro.

Broadly parallelized this is recognized at once as the Animike of Minnesota, embracing in that term the gabbro and "red rock" Mesabi, the Pewabic quartzyte,* the black slates and gray quartzytes and the Ogishke conglomerate. At the same time the upper quartzyte is provisionally parallelized with the true New York Potsdam sandstone quartzyte.** This quartzyte with its Potsdam characters, including a primordial fauna, is found to exhibit characteristic outcrops in Barron county, Wisconsin, southern Minnesota, southeastern Dakota as well as in New York, and in Vermont where it early received the designation "granular quartz."

Subsequently this unconformable quartzyte was traced through the Marquette iron region of Michigan, and its unconformity on the iron-bearing rocks was observed and figured at two points.

The iron-ore rocks of the region of Marquette are, in the 16th report, made the parallel of those of Vermilion lake in Minnesota, and hence a part of the Keewatin which underlies unconformably the Huronian. The dioritic group and the gold-bearing serpentine group of Dr. C. Rominger are, together, made the equivalent of the sericitic series (i.e., the Keewatin) of Minnesota, embracing in that the schists that hold the jaspilyte at Tower, the conglomerate of Stuntz island, the Kawasachong rock, the green conglomerates at Ely, the lower portion of the great conglomerate at Ogishke Muncie lake,* the dolomyte at Ogishke Muncie lake, and the "greenstone belt," in general, of the map accompanying the 15th report. This series of rocks is not found in the area of the original Huronian.

---

* For a description of the Pewabic quartzyte see p. 86, 16th report.

** Compare "A great primordial quartzyte." American Geologist, March, 1888.

The iron-bearing rocks of the Penokee-Gogebic range of Michigan and Wisconsin, however, are not considered to be in the same formation as those at Vermilion lake. They are made to be the equivalent of the slates and iron-bearing rocks of the Animike of Minnesota, and hence of the true Huronian. The evidence of this need not be repeated at this place, although it is not expressed fully in the report here summarized. It will be given more fully in a later chapter in this report. †

An important point was reached, in the 16th report (pp. 97–98), in the separation of the Ogishke conglomerate from the greenstone agglomerate on which in some places it must lie unconformably. They seem to have both been affected by the gabbro epoch of disturbance, and the gabbro was found in different localities to lie on the gently inclined strata of one and the nearly vertical strata of the other.

Facts confirmatory of the origination of crystalline acid eruptive rock, both *in situ* and in form of overflow, from fragmental strata, as before reported in the 15th report, are given again on pp. 104–108 in the 16th. These fragmental strata seem to be some part of the Keewatin, and were originally conglomeritic.

Bearing on the question of the age of the gabbro-red-rock flood, which is taken by the Wisconsin geologists to be the base of the Kewenawan, or Cupriferous, of the lake Superior region, some facts were reported in the 16th report (pp. 85, 87, 88) which show that the gabbro began to be extruded during the deposition of the great quartzyte which overlies the Animike, and that the great mass of the gabbro is of not much later date, i. e., of the age of the primordial quartzyte of the Northwest which is considered to be of the age of the Potsdam of New York and the "Granular Quartz" of the Taconic.

---

* My brother, however, regards the Keewatin schists as bearing no relation to the Serpentine group of Rominger. See p. 343.

† On the other hand my brother is disposed to regard the Gogebic ore-bearing rocks as having about the same horizon as those at Marquette, which he does not admit within the Huronian; (pp. 188 and 194). The Penokee rocks, however, he would make Huronian.

2. THE VARIOUS STEPS OF PROGRESS.

If we revert now to the list of problems that were unsolved touching the crystalline rocks of the state in 1872, when this investigation began, we shall see that, by the aid of the geologists of Wisconsin and Michigan, great advance has been made in settling some of the questions then pending.

1. The uncertainty respecting the possibility of making a stratigraphical subdivision of the "Azoic" of Foster and Whitney, or the "Archæan" of J. D. Dana, exists no longer. There is a more or less extended subdivision, sometimes into only two parts but more frequently into three or more, which is accepted not only by the geologists of the Northwest but by geologists who are at work on this group of rocks throughout America and Europe. So far as Minnesota is concerned this subdivision can be carried still further, and six members of the "Azoic" (if the Huronian be included in it) can be described which maintain a constancy of character and stratigraphic position extending into Wisconsin, Michigan and Canada, such that they have to have individual description.

2. The terms Huronian and Laurentian were applied to two of these parts by the Canadian geologists. Though misunderstood, by reason of the contradictory and varied definitions that have been given these terms by geologists later than the descriptions of Murray and Logan, when they are compared with the typical regions in Canada they are found to have definite and easily recognizable application to stratigraphical horizons which are extended over the whole Northwest, if not over the world.

The Huronian formation is satisfactorily established as the equivalent of the Lower Cambrian of Sedgwick. This conclusion is not wrought out in any of the annual reports of the Minnesota survey. It is an inference, however, from two other facts which have been indicated in the foregoing synopsis of the Minnesota annual reports, and it has been urged elsewhere by the writer. These two facts when united constitute a demonstration as incontestable as any mathematical formula, viz.:

The Lower Cambrian is equal to the Taconic,
The Huronian is equal to the Taconic,
ergo
The Lower Cambrian is equal to the Huronian.

We shall not stop here to bring forward anew the evidences on which these premises are based, but will proceed to mention other advances that have been made since 1872 in a knowledge of the crystalline rocks of the Northwest.*

4. The foregoing conclusion involves premises which themselves were doubtful in 1872, and which, in the opinion of the writer, are sufficiently established to be admitted as truths. The first is, that the Huronian of the Canadian geologists is the same formation which was named Taconic by Dr. Emmons of the New York geological survey. It makes no difference except in the greater difficulty involved in making this fact appear to the satisfaction of geologists, how long and how honestly the Huronian has been sustained by competent geologists, nor how long the Taconic has been as honestly ignored by the majority of opinion; if these names were actually applied to the same formation, the sooner it be acknowledged by American geologists and the proper adjustment be made in nomenclature, the better it will be for American geology and the credit of American geologists.

5. The other doubtful premise involved in the conclusion (3) above mentioned, can be considered doubtful no longer, viz.: The Lower Cambrian is the equivalent of the Taconic. There are some who bring trifling objections to the actuality of the Taconic at the horizon of the Lower Cambrian, but the evidence is so strong and is based on so large a mass of concurrent fact and testimony that it is practically demonstrated.

6. The Animike rocks having been shown, first by Prof. R. D. Irving, and subsequently by the Minnesota survey, to be the

---

* On the identity of the Lower Cambrian with the Taconic, see the writer's papers:

Notes on classification and nomenclature. *Amer. Naturalist*, August, 1887.

Some objections to the term Taconic considered. *Amer. Geologist*, March, 1888.

A great primordial quartzyte. *Amer. Geologist*, March, 1888.

Report of the American sub-committee on the Lower Paleozoic, to the London International Congress of Geologists. *Amer. Geologist*, September, 1888; also the report of the Congress.

The same view has long been held by Jules Marcou, J. Barrande, and by Dr. E. Emmons, and by other geologists later. Compare S. A. Miller. The Taconic system as established by Emmons and the laws of nomenclature applicable to it. *Amer. Geologist*, April, 1888. Also A. Winchell. The Taconic question. *Amer. Geologist*, June, 1888. C. D. Walcott. *Bulletin No.* 30, *U. S. Geol. Survey*, and *Amer. Jour. Sci.*, March, April and May, 1888. Mr. Marcou's principal papers are: The Taconic system, and its position in stratigraphic geology. *Proc. Am. Acad. Arts and Sci.*, Vol. XII, 1884. American geological classification and nomenclature, May, 1888.

On the identity of the Huronian with the Taconic; see, The crystalline rocks of the Northwest, N. H. Winchell, vice-presidential address, A. A. A. S., 1884. At a much earlier date the same view was held by E. Emmons, and by J. Marcou. It has also been stated by A. Winchell in the 16th report, p. 170.

equivalent of the original Huronian, it follows that they are also the equivalent of the Taconic and of the Lower Cambrian, and belong within the primordial zone of Barrande, although the distinctive fauna of the primordial has not yet been found in the typical Animike region.

7. The Laurentian rocks, of the Canadian geologists, are divisible into three parts, having different genesis and age. This fact has not been recognized, so far as the writer is aware, except by the Minnesota survey. These three classes of Laurentian (because they have all been so styled by the Canadian geologists) have been separately recognized by different geologists, both Canadian and American, and conflicting inferences have been drawn from them, which have tended to unsettle the whole foundation on which the Laurentian rests. Some have seen valid reasons for supposing the Laurentian older than the "Huronian" and conformable with it, and have given the details of the facts which show it. But others have seen another class of evidence, equally valid, that tends to make the "Laurentian" rocks of eruptive origin and more recent than the Huronian. And again some similar syenitic rocks have been described by the Minnesota survey* mingled in great masses and areas with the Mesabi gabbro. These three classes have been observed and described in Minnesota, as rehearsed in the foregoing synopsis of the Minnesota work. It is believed that these distinctions are fundamental, and that they extend throughout the Northwest, and that when they are recognized generally by observers many of the apparent discrepances that have been noted respecting the Laurentian will disappear.

8. The Laurentian, then, is easily divisible into three parts, but it would not be claimed, probably, by any one, that the same stratigraphic term should be applied to them, and the question may fairly be considered to which of them does it belong.

Besides the subdivision of the "Laurentian" into three parts, as above noted, a different separation has been recognized by some, viz.: into *gneiss* and *crystalline schists*, on the assumption that the original Laurentian contained such schists. This is a necessary and valid subdivision, from that point of view, and was adopted by Prof. R. D. Irving. It is also approved by my brother, A. Winchell, in the 16th report.

9. The "Laurentian" is therefore partly the result of change

---

*It seems very likely that this so-called Laurentian has also been described in Canada in the regions where the eruptive gabbro is found.

in situ from old sedimentary strata of Laurentian age, and partly the result of eruptive forces which have caused an extrusion and partial overflow over later sedimentary strata of some of the fused material of the same old strata. Such extrusion has taken place at least at two epochs, and the later one is of the age of the gabbro and may have not risen from so great a depth as the former.

10. For reasons which have been mentioned elsewhere* it appears that by hydro-thermal fusion the deep-seated sediments of the super-crust became crystalline; also that the normal super-crust is necessarily acidic; also that any eruption from the fused portions of the super-crust would not only produce an acid eruptive rock when cooled, but that in the later history of the earth (Cretaceous and Tertiary) such acid extrusions could rarely if ever reach the surface of the earth, but would form laccolites amongst the strata overlying the zone of complete fluidity.

3. THE RESULTS OF THE INVESTIGATION SO FAR AS THEY APPEAR AT PRESENT.

If these steps of progress be applied specifically to the crystalline rocks of the state, we shall find some such history as the following delineated therein with greater or less distinctness.

The Laurentian age.

The name Laurentian is applied here essentially to the "fundamental gneiss." It does not go so far back as to include the first rigid primeval crust that formed from cooling nor so far subsequent to it as to embrace any noteworthy strata of basic minerals that might indicate a formation different in nature, or manner of genesis from the gneiss. In other words it does not include the "crystalline schists." The rock is essentially gneiss, either granitic or syenitic. It resulted from the fusion and recrystallization of the earliest sediments. It occupied a long period, and one that must have been marked by profound quiet, and by uniform conditions. The siliceous accumulations that were the product of oceanic waves and beaches, began in the shoal parts of the ocean and widened as the dry land increased in area, forming the nuclei of the continents. These sediments must have been siliceous, because such only would remain undissolved by the hot and finally alkaline waters of the ocean. When they had accumulated to a great thickness they were buried under sediments of another kind, those of the "crystalline schists," marking the opening of another epoch in geological time. Wherever they had been raised above the level of the ocean they constituted the only land areas that existed, and perhaps till this day those areas, or some of them, have not again been submerged.

---

* Compare "Some thoughts on eruptive rocks with special reference to those of Minnesota." N. H. Winchell, A. A. A. S., 1888.

Distribution of the Laurentian in Minnesota. A large part of Minnesota is occupied by this fundamental gneiss. It is not to be supposed that all the area now occupied at the surface by this gneiss, was originally the land area of the state at the time of the close of the Laurentian age. The lapse of time has brought the earth through many vicissitudes. The original area of the Laurentian has been increased at the surface by the growth of the continent which has steadily expanded and risen higher above the ocean's level. As the later strata have successively been elevated to dry land they have been subjected to such destructive action, first of the ocean's beach-line, and afterward by the agency of the atmosphere, that they have been worn back and have uncovered the gneiss over extensive areas where it was at first hid.

In Minnesota this gneiss must have extended diagonally across the state from N. E. to S. W., crossing the Mississippi river and occupying the region of its headwaters about Itasca lake, and including the region of the upper waters of the Minnesota river. There may be spots, or considerable areas, within this original gneissic belt, where by subsequent deep-seated hydrothermal fusion these primitive Laurentian sediments have been rendered plastic and then fluid, and have by pressure been extruded through fissures in the crust to the surface, or have been uncovered as laccolites by the destruction of the overlying strata; but wherever these exist they are presumed to show their later origin by their non-gneissic structure, or by their overlying some later sedimentary strata. The distinction, however, between the eruptive condition of the fused Laurentian sediments, and the primitive sediments that have been converted *in situ* into the fundamental gneiss is one that requires more study before it can be defined. That both conditions exist there is no question; that they can always be distinguished is not to be affirmed.

This Laurentian gneiss is represented by the Basswood lake and perhaps the Saganaga lake granites, and probably by the gneisses that are found in the Minnesota valley from near Morton northwest to Big Stone lake. Northwestwardly from the Basswood area are others of similar gneiss, which have their extension northeast and southwest, nearly parallel with the extension of the other areas. Indeed the geographic distribution, no less than the geological facts that are observed in the field, favors the supposition that these alternating gneissic belts in the northwestern part of the state show either simply the denuded crests of stratigraphic anticlinals or of upward swells of the iso-hydrothermal fusion that has affected the ancient Laurentian sediments. This question is one that requires further investigation. It is referred to again under the head "Problems still unsolved."

Eruptive Syenite. Closely associated with these belts of fundamental gneiss are areas of massive eruptive syenite. It is a fortunate circumstance that the apex of one of the anticlinals of the gneiss runs near the present natural surface, and its manner of transition from sedimentary to crystalline rock can be observed. It would be more consistent with the tilted, even vertical, portion of the beds at the points where this transition has been observed, to suppose the change was due to the varying depths at which planes of equal hydro-thermal fusion ran below the surface at the time it took place, than to suppose it is due to an actual undulation in successive anticlinals of the same stratigraphic horizon. This favorable apex for observing the genesis of gneiss is in the line of the gneissic belt that runs southwestward from the west end of Gunflint lake, and which apparently is continued in the form of erupted syenite in the Giant's range southwestward from Birch lake. It was observed particularly on the Kawishiwi river (15th report, p. 353) and about the south shore of lake Kekekebic (15th report, p. 367; 16th report, p. 103–107). Whether that part of this gneissic belt which is referable directly to a change *in situ* in sedimentary materials be of the same age, i. e., on the same stratigraphic horizon within those sediments, as others that exist further northwest or not, they are here considered to belong to the Laurentian age in so far as they have not been entirely fused and extruded in a liquid state so as to form erupted rock.

It has already been remarked that the erupted massive form of the acid Laurentian is closely associated geographically with the gneissic. Whether they were of contemporaneous origin is not certain. But that the erupted condition was in some cases produced subsequent to the age of the "crystalline schists" is evident from the fact that such rock replaces and cuts those schists. This fact has been recorded many times. One of the most remarkable replacements of the dark schists by the bodily transference of syenite is seen north of Gunflint lake, and is described and mapped by Mr. Grant in this (17th) report. That some other areas of syenite were of considerably later date, possibly so late as to have flowed over the Keewatin (greenish, or hydro-mica) schists is indicated by observations made by H. V. Winchell along the Giant's range southwest from Birch lake, and by myself on the shores of Kekekebic lake, where a conglomerate porphyroidal rock passes into gneiss, and directly overlies some Keewatin schists. That other of the erupted syenites of the state are as late as the gabbro, and hence overlie the Animike, is shown not only by the syenites associated in mutually intermolten sheets with the eruptive gabbro that overlie the Animike, but also by the observations made at the Aurora mine in Michigan (16th report, pp. 58 and 187). This is indicated also by the observations and conclusions of Maj. T. B. Brooks and by Dr. C. Rominger in respect to the age of some of the granite rocks of Michigan.*

The age of the Vermilion schists, or "crystalline schists."

It has been remarked† that the mineralogical difference bebetween the gneisses and the dark "crystalline schists" is so great that it is allowable to attribute to the latter a different method of genesis, one sufficiently distinct to have introduced a different geological time or age. This fact was recognized in 1886, and the rocks that mark the opening and continuance of this new epoch of time were separated under the name "Vermilion group." A similar series of schists had been noted by Lawson in the region of the Lake of the Woods in 1885,‡ but, while separated by him into two parts, viz., "Schistose hornblende rocks," and "mica schists," had been by him embraced under the general term of "Keewatin series," and considered as the basal part of that series, and assigned to extra-Laurentian time. Subsequently Mr. Lawson identified the mica-schist group

---

*T. B. Brooks, on the youngest Huronian rocks south of lake Superior. *Am. Jour. Sci.* (3), xi, 206.

Carl Rominger. *Geological Survey of Michigan*, Vol. IV, p. 22.

†A. Winchell.

‡Report on the geology of the Lake of the Woods region. Report C. C. of the Canadian survey, 1885, pp. 37, 54.

and the basal portions of it (the hornblendic schists and the eruptive features that characterize the horizon) in the region of Rainy lake, and has given a description and a name for the mica schists. (*Am. Jour. Sci.* June, 1887, p. 473). He includes the mica schists under the term *Coutchiching*, and supposes the changed eruptive rocks which intervene geographically between them and the belt of Laurentian gneiss lying next north (along the northern shores of the southern part of Rainy lake) to be of later date than the schists.

A similar group of mica and hornblendic schists had been noted in Michigan by Brooks and in Wisconsin by Irving and been placed in the Laurentian. Rominger included the same in his "granitic group" (Geol. Mich. Vol. IV, p. 17–18). Higher in the stratigraphic series, i. e., between the magnesian soft schists and the gneiss and gabbro of the post-Huronian rocks,* another formation of mica schist was observed by them, which they placed near the summit of the "Huronian." They gave neither of these any special designation. In New Hampshire the "Montalban series" is one essentially of mica schists, but† whether it can be parallelized with either of the northwestern horizons of mica schist is a question which the future alone will be able to answer.

Hornblende schists converted to mica schists. To the writer, however, the micaceous and the hornblendic characters seem to be so blended, and the one so frequently substituted for the other, that the two parts described by Mr. Lawson appear to be only phases of the same set of rocks. The hornblendic condition, as schists, is without doubt the fundamental and primary one; and that one is found nearest the gneiss of the Laurentian. Hornblende is easily converted into biotite; biotite has so close relations with muscovite that it is sometimes twinned with it in the same crystal; muscovite is replaced both across the bedding and along the strike by hydro-mica or pearl-glimmer, and the last passes insensibly into the talcoid "Keewatin stuff"‡ of the Keewatin series. There is a conformable succession, both genetico-mineralogical and stratigraphical, from the hornblende schist through the mica schist into the hydro-mica schist, by which these are bound fundamentally into one group, as placed by

---

* Geology of Wisconsin, Vol. III, 1873-79, pp. 93, 145, and table between pages 436 and 437.

† Geology of New Hampshire. C. H. Hitchcock, Vol. II, p. 112.

‡ A. Winchell. Sixteenth report, p. 343.

Lawson, and no other sort of transition is known or indicated. On the other hand, bearing in mind the strong mineralogical break, or contrast, between the gneiss and the hornblende rock, there is not so close a mineral relationship with the Laurentian. There is also, in some places, as profound a stratigraphic break and non-agreement. This is shown in numerous descriptions and illustrations not only of Mr. Lawson, but also by the 15th and 16th reports of the Minnesota survey. Mr. Lawson emphasizes this fact by a remarkable inference, viz., that the Laurentian is eruptive and of later date than the Keewatin schists. Not to dwell on this inference at this time it is sufficient to call attention to it to show the probability of a plane of profound discontinuity between the Laurentian, as here defined, and the Vermilion group.[*]

Nature of the transition from the Laurentian to the Vermilion. As to the nature of the dynamic agent which introduced this change in the crystalline rocks at this horizon, it is indicated by the nature of the rocks themselves. Primarily they are characterized by the minerals that constitute a basic eruptive. They are found to exist at first as structureless knobs of dioryte or doleryte. These lie nearest the gneiss (15th report, p. 330). They are flanked by basic rocks of various modifications, among which hornblende schist is predominant. Gradually, on receding from these black knobs, a sedimentary structure becomes apparent, and the hornblende is replaced partially or wholly by black mica. At last the rock is changed to a nicely stratified mica schist which at first is perhaps very dark-colored and firm, with little free silica, and subsequently, with an increase of silica, is striped with distinct strata of granular silica. As the dark mica still further fades out the mass is converted to a fine granulyte or quartzyte, or a light-colored mica takes its place and the whole passes into sericitic schist or graywacke.

It is not always the case that all evidence of molten condition is wanting at this horizon of transition from the gneiss. But it is very slight at most of the sections which have been described.[*] If, however, but a single unquestioned occurrence of eruptive conditions be found at this point it is sufficient to warrant the hypothetical introduction of a general eruptive epoch, so widespread as to constitute a change from one system of rocks to another. No one can read the descriptions given by Mr. Lawson, or some of those contained in the 15th and 16th reports of the Minnesota survey, without recognizing not only one point but numerous points where eruptive characters are stamped at this horizon not only on the basic rocks of the Vermilion but also on those of the acidic "Laurentian." They mutually interpenetrate each other in the form of transverse dykes and mutually embrace isolated fragments separated each from the other. It seems to be abundantly demonstrated that some sort of dynamic change was introduced. The only inference that such a demonstration points to, in the light both of the contrasted lithology and the interrupted stratigraphy, is that of volcanic action.

---

[*] Compare, A. Winchell; 15th Report, pp. 41, 43, 87, 97, 180: H.V.Winchell; 16th Report, pp. 407, 416, 417, 419, 455, 456: N. H. Winchell; 15th Report, pp. 291, 338, 349; 16th Report, pp. 76–77: M. E. Wadsworth; 15th Report, p. 331.

[*] Compare, however, Lawson, Can. Rep. 1885. C. C. p. 41; Am. Jour. Sci. June, 1887, p. 477.

Having now fairly stated the nature of the change which is presumed to set off the Vermilion rocks from the Laurentian, it is necessary to consider, further, whether the gradual and conformable conversion of the Laurentian beds into the Vermilion, such as has been seen at many places, and which indeed is the most frequent manner of transition,* is consistent with the hypothesis of an epoch of eruption. It should be remembered that the beds do not now hold the position they had when they were deposited. They stand now nearly vertical. While this upturning facilitates the deciphering of their history, it has been accompanied by such changes in the crystalline condition of their elements that a screen that partially conceals their history has been thrown over them all; yet through this screen can be seen the outlines of their historic and dynamic genesis.

Admitting the actuality of a period of volcanic action at the opening of the Vermilion age, it is evident that the eruptions would take place only at centers of intensity of pressure. Once located, such vents would for longer or shorter periods continue to send forth the eruptive matter. In the presence of the almost world-covering ocean these materials would be at once distributed, dissolved, deposited, in the same manner as sediments at the present day, excepting only that probably the solvent power of the ocean's waters was greater than at the present time. The former sediments having been almost wholly of an acid nature,† such that when crystallized again they constitute the fundamental gneiss, they must have been accumulated slowly. But on the advent of this new supply of material, which is so rapid that it can not all be worked over by the ocean so as to be dissolved and its alkaline elements extracted, the erupted materials are thrown down in the condition of stratified sediments, retaining to a great extent their chemical composition. In the periods of comparative quiet these basic materials are interbedded with more siliceous materials, such alternations taking place as long as the supply of basic material is intermittent. Thus might be formed a great series of strata, surrounding the volcanic centre, thousands of feet in thickness, which would be made up of variously interstratified or mixed siliceous and basic sediments. Sometimes there would be intrusions of purely basic doleritic rock among these sediments, at different horizons, due to the bodily overflow of sheets of lava among the sediments,* in a manner similar to the interbedding of trap rock in the Kewenawan at a later date. In other places these eruptions might take place somewhat later, involving in fracture, upheaval and mixing the last made strata in forms of various fragments and breccia in the molten rock that escaped.** Such an epoch of disturbance, sufficient in its force to cause the outflow of basic rock from a deep source, would probably be sufficient to fuse and cause the outflow of some of the sedimentary rock that already had been formed. Thus the basic and acid rock would mutually interpenetrate, and a series of fractures which would be filled by the injection of any fused material that was adjacent, would be perpetuated to the remotest time in the form of transverse and more or less concordant dikes and by breccias composed of the two rocks.

---

* Mr. A. C. Lawson has described such in his report on the region of the Lake of the Woods, pp. 73, 76, 83. See also A. Winchell; 15th Report, pp. 97, 101, 178; 16th Report, pp. 264: H. V. Winchell; 16th Report, pp. 405, 415, *et passim*: N. H. Winchell; 15th Report, pp. 296, 298; 16th Report, pp. 69, 70, 76.

† That is, containing over 60 p. c. of silica.

It is manifest, therefore, that the supposition of the advent of a characteristically eruptive era, closing the quiet Laurentian sedimentary age, will account for both an unconformable and a conformable transition, such as are seen, from the Laurentian to the Vermilion.

Effect of hydrothermal fusion. It is necessary, before proceeding to the consideration of the next age, to call attention to another great fact in connection with the history of the Vermilion. Nothing is more evident to the geologist who carefully inspects the Laurentian and Vermilion strata, than that they have had, in some respects, a common experience. This, however, is subsequent to the date of the origination of the rock masses, and has had a tendency to so unify their mineral characters as to blend them, in the opinion of some geologists, indissolubly into one system. They contain, excepting the eruptive diabases, etc., at the base of the Vermilion,— essentially the same mineral components; but those components are differently distributed and exist in very different proportions. These minerals are interlocked with each other in crystalline contact. It is very difficult to affirm, in many places, any fragmental grains. They lie in such continued parallelism in long sheets that there is no natural agent except sedimentation that can be appealed to to account for the stratification. The strata do not consist of individual minerals, that is, any single stratum may contain several minerals, but they change in relatively proportionate amounts in a direction across the strike, and this slow change, which on weathering brings out either light or dark bands, is so gradual that some of the strata or some parts of the strata, can not be separated from the others by any accepted designations. Within the same band the gneissose aggregation changes to a schistose. While in a general way it may be said that the mica schist alternates with what Mr. Lawson has conceived to be a series of thin gneissic dykes in as many sedimentary beds of mica schist, it is equally true, and equally as evident on inspection, that the schist fades out across the beds, into gneiss by a change in the relative amounts of the constituent minerals. It is very certain that if the schist, in such places, be attributable to sedimentary origin the gneiss is equally so.* Indeed often within the gneiss itself are distinguishable narrow, parallel belts of varying color and lithology at some distance from the horizon at which the general gneiss mass began, which must be attributed, as certainly to the same cause as in the schist. These only lack the dark coloring minerals to show their nature more evidently, and their similarity of origin with those unquestioned parallel belts that mark the schist.

---

* H. V. Winchell seems to have encountered such in that great extension of the Vermilion northwestward from Vermilion lake to Rainy lake. See, specially, 16th report, p. 425.

** See the 15th report, p. 333, and p. 337.

This crystallizing and unifying of the mineral characters must have taken place in these strata while they were yet buried at considerable depth below the surface, or at least at such a depth that they were affected simultaneously by hydro-thermal fusion.

---

* Compare H. Reusch, *Boemmeloen og Karmoen med omgivelser geologisk beskrevne* (English summary), p. 389, 1888.

Whether before, during, or subsequent to the process of upturning which has brought them both to a vertical attitude, it is not necessary here to inquire. Indeed, this is yet one of the "unsettled problems."

The Keewatin schists.

This term is here used in a sense somewhat restricted from that in which Mr. Lawson first applied it, inasmuch as it does not include the crystalline schists. This change, however, will doubtless be considered allowable, since Mr. Lawson himself seems to have separated the original group into two series by the application of a distinctive term to the mica schists — the Coutchiching.*

Conformable transition from the Vermilion. It has already been stated that structurally there is a conformable transition from the Vermilion to the Keewatin. This has been found to be the case without exception, so far as the Minnesota survey is concerned, and it seems not to be contradicted by any facts reported by Mr. Lawson. Indeed, so far as Mr. Lawson has reported any facts,** they tend to harmony with the facts and conclusions of this survey. Very favorable opportunities have been afforded for the minute inspection of these beds where they pass to the Vermilion, in many places, and they are reported in the fifteenth and sixteenth reports. There have been five different geologists, engaged within the last three years by the Minnesota survey, who have made independent examinations at this horizon of transition, and at separate places, and in every instance they have reported a gradual and conformable transition from the Vermilion to the Keewatin.

There is also a corresponding gradual change in the crystalline condition and the composition of the beds. While the materials are referable very largely to the same source as the materials of the Vermilion, there is an increase of quartz and a loss of mica in ascending in the strata. The schists become sericitic, or chloritic, or argillitic, and are interbedded with graywackes and agglomerates; the last prevail near the top and indeed seem to have introduced the marked eruptive characters that distinguish the next formation.

Nature of the Keewatin rocks. It appears, from the character of the rocks of the Keewatin, that active volcanic vents existed throughout the whole period, and that the ejectamenta were received in the waters of the surrounding sea. The strata contain much silica, in rounded grains and pebbles, indicating the waning of the volcanic supply and the influx of sedimentation similar to that accumlated during the Laurentian. There are dykes and various diabasic rocks associated with the Keewatin strata, some cutting transversely and some nearly, but not quite, parallel with the strike, some of which are certainly of a later date, but of which some seem to belong to the age of the Keewatin. Whether any of these have any possibly traceable connection with some of the old volcanic vents, existing within Keewatin time it is not now possible to state, but it is very likely that such connections will ultimately be established. At any rate the Keewatin closed by a renewal of active eruption as profound in its energy and its effect on the pre-existing strata as that which marked the close of the Laurentian. In the vicinity of Tower and thence eastward the rocks that evince this epoch of volcanic eruption have been insepcted at many places, and they are described with accompanying illustrations showing the crumpled and faulted condition of the earlier aqueous strata, in the fifteenth annual report (pp. 223–275). The rocks which resulted from this renewal of igneous forces form a conspicuous series and they have been traced almost continuously from Tower to the vicinity of Gunflint lake where they pass below the Animike. They show the same confused blending of stratified with massive rock as has been mentioned at the base of the Vermilion. In many places they constitute hills that rise one hundred to three hundred feet above the adjoining lowland levels, and consist of a greenstone that exhibits all the outward characters of diabase or doleryte. At many places this greenstone is agglomeritic, some of the stones showing, by a periphery of amygdaloidal structure, that they were immersed in a magma that differed from them in the amount of contained heat, or in their capacity for receiving and transmitting heat. The massive structure sometimes embraces large fragments rent from beds of stratified structure, and the massive structure itself sometimes acquires a faint lining and then a distinct banding which cannot be attributed to any other known agent than sedimentary action. The greenstone is frequently jointed in a columnar manner, forming basalt, in which cases it seems necessary to regard it as a primary basic eruptive. All the other modifications and exceptions which this greenstone exhibits causing a departure from the characters of a normal basic eruptive are to be referred to the action of the ocean on the erupted materials, or on the local rupture of the pre-existing strata and the mingling of the fragments with the new materials. It is evident that in some places these fragments would be gently covered and inclosed by new sedimentation (and such instances are shown on the south shore of Vermilion lake) producing the curious alternations of breccias and parallel strata, all of the same kind of rock, which have excited the wonder of more than one geologist. It is equally evident that in other places these fragments would be covered by an overflow of erupted material that did not come into contact with the ocean's distributing action, and there would result a basalt containing angular masses of fragmental strata. It has been observed that apparently the most massive rocks of this epoch change by weathering into a green chlorite or even a sericitic schist, when they occupy the lower levels and come into contact with water, or where they are subjected to unsheltered exposure to alternating frosts and moisture. In this case the original rock shows, sometimes, a sedimentary banding, and the schistosity that results may or may not coincide with the direction of this banding. Throughout nearly all the region where this greenstone prevails, the schistosity has a prevalent direction northeastwardly, and that is also the direction of the general strike of all the sedimentary rocks; but there are exceptions in the case of the sedimentary strike, which are more numerous and extensive than any that have been found in the direction of the schistosity. The ease with which this schistose structure is developed on weathering, seems to vary with the composition of the rock, or at least with its original structure. Where the greenstone is evidently a true eruptive basalt which has never been subjected to the distributing action of sedimentation the schistose structure is faint, or is wanting, and rounded knobs of structureless massive rock rise above the general level of the country. When there is an intimation of the primeval action of water on the constituents of the rock at the time of their deposition, evinced either by the presence of siliceous grains, the inclosure of fragments of stratified masses, a generally lighter green color in the whole mass, or in an indistinct banding like sedimentary structure, the schistose structure is more quickly developed.

---

*Am. Jour. Sci., June, 1887, p. 477.

**Am. Jour., June, 1887, p. 477.

Vermilion iron ores. The Keewatin is the iron-bearing formation of the region of Vermilion lake. It contains the jaspilyte lodes which have been described at Tower in the 15th annual report. But it should be stated that these lodes seem to prevail in those parts of the formation that show most evidently the characters of massive and original eruptive rock, i. e., in the later portion. The knobs of jaspilyte at Tower are embraced in and penetrated by a green schist which at the surface is easily excavated, when a schist, but which at greater depth sometimes becomes a massive green rock, and which in the main must be considered an original eruptive. At short distances from the knobs, even on the slopes an evident sedimentary structure supervenes, the beds being nearly or quite vertical.

Origin of Jaspilyte. It is not necessary here to reconsider fully the question of the origin of the rock known as jaspilyte. Various considerations are given in the 15th report that go to show that it is of sedimentary origin, embraced as foreign masses in the green eruptive rock of the region. Much more study has since then been given to the subject, and while the facts and arguments then relied on are still valid some other problems have arisen which need to be solved in order to make the hypothesis of its sedimentary origin entirely satisfactory. They can be briefly referred to, viz.:

Why is the silica of the jaspilyte so uniformly of very fine grain, and of so uniform a grain?

Why does the jaspilyte accompany the most evidently eruptive parts of the Keewatin, and why is it not found in important masses in those parts that have plainly a sedimentary structure?

It seems quite remarkable that the jaspilyte, on the sedimentary hypothesis of its origin, should not vary perceptibly in the size of its siliceous grains. Reference is here made to the ultimate quartz grains into which it disintegrates on being long weathered. When, in the stratified schists, some small pebbles from the jaspilyte are disseminated in the manner of sedimentation, the pebbles themselves, as constituent elements in the stratified mass, are seen to vary in size considerably, some of them being no larger than the eye of a needle, and others as large as pease, or even much larger. The same is true of pebbles of other silica, such, for instance as those of segregated or chemical silica which does not show the finely granular structure. But when these pebbles of jaspilyte are examined more closely they are found to be made up of almost microscopic quartz grains of the same size. The question refers to the size of these

If they are the product of sedimentation, it would be in accordance with usual observation that they would have been collected and deposited under the action of varying currents and would vary in size from place to place, or from structure to structure (within certain limits) and some of them would be expected to be mingled with other sorts of sedimentary materials. Some observations have been made, indeed, which indicate the mingling of fine siliceous grains, supposed to be the same as the fine grains of the jaspilyte, with the sedimentary green schists in the vicinity of Tower,* but in these cases, and especially in the case of principal masses of jaspilyte that are mined at Tower, it is not yet sufficiently shown that the ultimate grains of which the jaspilyte consists, manifest such a variation as is here indicated. Indeed it is quite possible that all the siliceous grains that are seen disseminated through the green schists, as seen at Tower, are compound grains, derived as fragments from jaspilyte that pre-existed as such, and that each one can be reduced, on examination, to the same minute granules as the jaspilyte itself. Therefore the question remains unanswered—why are the ultimate granules of the banded jaspilyte of so uniform a size, and so uniformly fine?

Again, it seems quite remarkable, on the sedimentary hypothesis of the origin of the jaspilyte, that it should be found, in its most typical forms and largest amounts, embraced in a rock which manifests the least of the characters that indicate sedimentary forces, and surrounded by rock that manifests unquestioned, or almost unquestioned, eruptive forces in its manner of origin.† This association is hard to explain except on the eruptive hypothesis for the origin of the jaspilyte. It might be said, with much reason, that in the midst of the basic eruptions, or at intervals of rest from basic eruptions, some acid eruption took place, and that the erupted matter assumed such forms, and such relations to the basic, whether in the presence of oceanic waters or on land, as the circumstances required, in just the same manner as the materials of basic eruption. To this the mineral nature of the jaspilyte is the greatest obstacle.

Name. The massive "greenstone" stage of the Keewatin has no distinctive name. It has sometimes been referred to as the

---

* Fifteenth report, pp. 226–230.

† Attention has been called to the distribution of the jaspilyte masses by Mr. H. V. Winchell *American Geologist*, January, 1889. *The diabasic schists containing the jaspilyte beds of northeastern Minnesota.*

"Kawasachong rock," since it forms the falls of that name at the mouth of the Kawishiwi river, on the south shore of Fall lake. But it is not desirable that such a name be perpetuated. *Kawishiwin* would be better, and it would be appropriate since this river runs for many miles, and some of its tributaries for many more, over rock belonging to this epoch of the Keewatin.

Parallels of the Keewatin. The writer has seen at but one place in the Northwest, outside of Minnesota, what he believes is the stratigraphic equivalent of the Keewatin. This belief rests entirely on lithological resemblance, with some general stratigraphic parallelism. In general, the groups which Dr. C. Rominger has described as "serpentine group" and "dioritic group,"* in the region of Marquette, exhibit the characters of the Keewatin. There may be, as thought by him, an essential difference between the dioritic and the serpentine groups, but their affinities are very close, and indeed nearly all the characters, in limited areas, are found in the Keewatin. The serpentine rocks may ultimately be found to consist of the old volcanic cones, now tilted to lie at an angle of 90 degrees, more or less, from the position they originally occupied, from which issued the ejectments that were consolidated to form the dioritic schist group. In that case they would fundamentally be of about the same age as those schists. However that may be, no one can read the careful description of the dioritic group by Rominger, be he familiar with the Keewatin, without being struck with the great mineralogical similarity. (See also 16th report, pp. 47–48.)

There is, however, an important evidence of this parallelism to be drawn from a comparison of the stratigraphy. In the Marquette region the mica schist group is but feebly represented, and is not at all shown by Rominger on his map of the region. It is included by him in his granitic group. But the dioritic group comes at once into contact with the granitic rocks of the "granitic group." This is shown to be interbedded sometimes with the base of the dioritic group, and the granite to be apparently produced sometimes by the fusion and extrusion of some of the beds of the dioritic, or from some of the lower strata, forming knobs and sudden enlargements of granitic rock within the schists of the dioritic group.† The same kind of indistinct, incipient crystallization as described by him has been noted at about the same horizon in the schists of the Keewatin north of

---

*Geol. of Mich., Vol. IV, pp. 22, 24, 26, 27.

† Geological survey of Michigan, Vol. IV, 1881.

Gunflint lake, and between Ogishke Muncie and Kekekebic lakes, and the same gradual inter-bedded transition from the schists to a sub-granitic rock. In the same way also great overflow areas of acidic syenite or "granite" are found in connection with both.*

But the most remarkable stratigraphic coincidence is the relation of the Keewatin and the dioritic group to the overlying formation. In Minnesota it is the iron-bearing Animike, and at Marquette, it is the "iron group," of Rominger. This relation is one of unconformity. For evident reasons, which need not be elaborated here, the "iron group" of Rominger is considered to be on about the same stratigraphic horizon as his "arenaceous slate group." They are not shown by him to be distinct, although he supposes them to be separated by the "quartzyte group," and in both of them are found important bodies of ore in the Marquette district. They have the same relations to the dioritic group, as described by him. and their geographic distribution, as separately delineated on his geological map, especially when taken in connection with his geological descriptions, is inexplicable on the supposition of their separate identity.

In the light of what has been published by the Minnesota survey respecting the unconformable superposition of the Animike over the Keewatin, nothing further need be said as to that fact. But when this unconformity is extended to the Marquette region, and the iron-ore beds there so much worked are placed above that line of unconformity, it may need a concise statement of the evidence to make it appear plausible. While it is in perfect accord with the published conclusions of the Michigan and Wisconsin geologists, to put the ore-bearing rocks of those states in the "Huronian," it is not in accord with them to separate that horizon from the dioritic schists which really embrace an ore horizon of an older date, by a plane of unconformity; but under the term "Huronian" have been grouped, in one essential concordant series of strata, all the rocks of the district younger than the fundamental gneiss or the Laurentian. Later Dr. Rominger has stated that some of the granite of the district is eruptive and of later date than the associated schists. (Geol. of Mich., Vol. IV, pp. 17 and 22.)

The reader is therefore referred to the following quotations from the descriptions of Dr. Rominger of the relation of the "dioritic group" to the overlying "iron group" and "arenaceous slate group."*

---

* The hematite lodes at Tower seem to have their representatives in the dioritic group of Rominger, but they have not proved productive enough to support regular mining. Such are mentioned by him on pp. 25, 27, 29, 30.

Page 72; Speaking of the surface rock of the environs of Negaunee and Ishpeming, which belong to the "iron-ore group," he says: "The strata are in an exceedingly disturbed condition * * * These disturbed beds lie, in every instance, directly, but very often unconformably, on chlorito-hydro-micaceous schists, or on crystalline dioritic masses which are constant associates of these chloritic schists." * * * "Overlooking the extremely plicated and corrugated condition of the strata, they form, considered in their totality, a synclinal basin, hemmed in between dioritic ridges."

Page 76; "The discordance existing between the dioritic and the iron-bearing rock groups is obvious in the majority of natural or artificial exposures, although it often occurs that they adjoin each other in parallelism."

Page 82; "The ore-bearing beds in the lake Superior mine lie in a steep inclination, with northern dip directly on the diorite, or on schistose beds belonging to this group, but in other parts of the mine the strata are seen to be bent and folded repetitiously, and to dip in the most irregular way."

Page 83; "The deposits visibly underlie the jaspery massive rock-ledges and repose in a much corrugated condition on the schists of the diorite group."

Page 86; "In the abandoned pits of the old Tilden mine, and in several neighboring natural exposures, the ore-formation is found to repose on the diorite, or on the schists belonging to this group, but, as it seems, always in discordance."

Page 108; Speaking of the "arenaceous slate group," he says: "The strata lie on the side of a diorite hill dipping under a low angle toward it in a northern direction, and a few hundred steps further east another body of these ledges lies in a slanting position on the diorite."

Page 114; "On the south side of the large cluster of diorite knobs, north of the New York mines, we generally see the ore-formation in direct contiguity with the diorite; but on the higher part of one of the rock bluffs another kind of stratified rock [i. e., the arenaceous slate group. N. H. W.] is found to repose on the diorite in seemingly discordant position."

These statements are sufficient to show that in the Marquette region there was a profound break, or unconformity, that separated the dioritic group from that next succeeding, as marked and as general, as that which separated the Keewatin from the Animike. The fact that it has not generally been recognized, and when so observed that its significance was not noted, may be explained by the great confusion that prevails at Marquette in all the dip and strike of the rocks, due to disturbances that involved both the older and the later terranes.

Further evidence of this parallelism is found in the fact that, in the same manner the Keewatin, and the "dioritic group" of Rominger, are unconformably overlaid by a more recent quartzyte, as will appear later in this review.

---

* Geology of Michigan, Vol. IV, 1881.

Jaspilyte is in the Keewatin and the dioritic group. There is a general lithological resemblance as already noted. It will be necessary here only to call attention to one. The Keewatin contains the typical jaspilyte deposits of Minnesota—i. e., those that have chalcedonic silica as their chief characteristic, and occur in curiously ribboned contorted bands or masses, affording a hard specular hematite. Although Dr. Rominger does not employ the term *jaspilyte*, he seems to make several references to it in connection with his account of the dioritic group. Such references may be found on pp. 27, 29, and 30. In other places it seems as if the descriptions that he has recorded of the phenomena of the iron mines, all of which he supposes to be in the "iron group," and not in the dioritic group, can apply only to the dioritic group. This is true particularly of some of those in the vicinity of Ishpeming. Dr. M. E. Wadsworth's observations and figures* seem to indicate the same. The manganesic soft hematite, and the limonitic ores, which are also "jaspery," are not believed to belong to the same formation as the hard jaspilyte-hematite, but to the overlying "iron group." It is true, however, that it is impossible, at present, to indicate fully the petrographic difference that may distinguish the jaspilyte-hematite of the Keewatin from the jaspery beds of the iron-ore group. That will be subject for further study.†

Possibility of rocks younger than the Keewatin, before the beginning of the Taconic. We have seen that the Keewatin was terminated by an increased eruptive activity, producing distinctively, in Minnesota the "greenstone range," or the Kawishiwin rocks. We have no distinct knowledge of any later sedimentary beds prior to the unconformably overlying Taconic (or Animike). There are, however, some problematical rocks that different members of the Minnesota survey have noted whose position in the stratigraphic column has not been determined. They have been designated *muscovado rocks*, and in some places they hold a position some distance south of the strike of the Kawishiwin and spread over several miles of area. It is not intended to discuss them here at any length. They may be some part of the Taconic, and it is only suggested that they may be a sedimentary formation that accumulated subsequent to the Keewatin before the submergence that brought the Taconic unconformably over it.

---

* Notes on the geology of the copper and iron districts of lake Superior. *Mus. of Comp. Zoology.* Geol. Series, Vol. I.

† The reader is referred to the rock "talcose conglomerate," described by Dr. E. Hitchcock in the *Geology of Vermont*, for a probable New England representative of the Stuntz conglomerate of the Keewatin. Indeed there is great reason to suspect that the Keewatin horizon in all its features exists in the "talcose slates" of western New England.

The age of the Taconic (Animike, Huronian).

How long an interval of time passed, and what its events were, separating the Kawishiwin epoch from the Taconic, it is impossible to state. But it is evident that there was a great change in the surface of the earth, wherever this succession is found, which tended to allow not only submergence of some of the pre-existing land area, but such general quiet, speaking broadly, as would allow slow sedimentation, and apparently the growth of plants and animals. The black carbonaceous shales and slates, or in other places the graphitic character of the rocks of the Taconic, where, as on Pigeon point, they have been metamorphosed, sufficiently indicate the presence of plant life in the Taconic. In other places faint tracings of rude forms, apparently of vegetation, have been observed on the sides of some of the black slates. But of these forms none from Minnesota have been carefully examined and described.* Of animal remains none have been found in Minnesota that belong in the black slates, but in the quartzyte overlying, some primordial fossils have been found† corresponding with the fauna of the Paradoxides horizon of eastern North America, indicating, so far as this evidence goes, the age of the "Granular Quartz," and of the Red Sandrock of Vermont. This formation seems to be represented in the Rocky mountains, where the primordial fauna has been mentioned by Mr. R. G. McConnell ‡ along the line of the Canadian Pacific railroad. Still earlier Mr. C. D. Walcott described it in Nevada. § There is no doubt that this formation is widespread. The coincident identity of the old Taconic with the "Lower Cambrian" and the Huronian need not be discussed here, and those who believe that these represent different rock-horizons will, of course, not accept the generalized history that is here indicated. To the writer there seems to be no way to group the terranes that are found in the Northwest, subsequent to the Keewatin, belonging in that general horizon that has been accepted widely as "Huronian," except to make them the parallel of that earlier-named system which was so long studied by Dr. Ebenezer Emmons, and by him named Taconic.

---

* Sixteenth report, pp. 78, 239.

† Thirteenth report, p. 65.

‡ Geol. Sur. of Can., 1886. Rep. D., pp. 29-30. Am. Geol., January, 1889.

§ Thirtieth bulletin, U. S. Geol. Survey.

The opening of the Taconic. So far as we know the Taconic was characterized, from New England to the Black Hills, by an epoch of increased submergence beneath the ocean. There is great reason to believe that all the earlier formations of the super-crust had been subjected to great flexure and uptilting before this submergence. In Minnesota the underlying beds are almost vertical, nearly everywhere, and the Taconic beds dip at angles generally less than 30°. It can hardly be supposed that throughout so great an area the subjacent strata could by any transformation be placed in verticality beneath the Taconic since the deposition of the latter, without equally disturbing the Taconic also. Indeed when such rupturing of the strata, since the deposit of the Taconic, has been observed, as in the region between Ogishke Muncie lake and Gabemichigama lake, the disturbance has involved the Taconic rocks also, and has turned them into various and excessive dip. Such exhibitions, however, are exceptional, so far as observations already made in Minnesota indicate. The Taconic strata maintain, both in Minnesota and Wisconsin, as in the Mesabi and Gogebic-Penokee ranges, a regularity of dip and strike, and a low angle of inclination which are not seen in any of the older rocks.

There is a conglomerate at the base of the Taconic. This is a fragmental, sedimentary conglomerate, embracing numerous rounded fragments from the earlier formations of the region. The lowest stratum seen in the Huronian, in the region north of lake Huron, is reputed to be a quartzyte which varies to a quartzose conglomerate, and by the accession of organic matter assumes a dark color, becoming a "slate conglomerate." In the latter form it has a wonderful development, both in Canada and in Minnesota*. It is the Ogishke conglomerate, of the Minnesota reports. It seems to be the Missasaugui quartzyte and the slaty conglomerate of the original Huronian area. This conglomerate is followed by an immense thickness of dark slaty rocks, often cherty, or flinty, frequently very dark-colored, generally siliceous, alternating with thin quartzytes, and grayish feldspathic quartzytes, all in conformable stratification, as a whole. Variously interbedded with these slates and quartzytes, from bottom to top, are beds of basic eruptive rock, and it is necessary to suppose that such eruptions must have been accompanied, in some places, by extensive disturbance and metamorphism. As a group, however, the Taconic strata sustain a uniformity of lithology, within allowable limits of variation, which marks them as one great series, which experienced essentially the same history over very extensive parts of America, and in that respect they show the same individuality as the Keewatin and the Vermilion, which names cover respectively the subcrystalline (earthy) and the crystalline schists of the Northwest. The Taconic is essentially the Olenellus group of strata of the primordial.

---

*On the passage of the quartzose condition into the slaty, each being pebbly, see Logan. 1863, Geology of Canada, pp. 55, 56, 594.

The iron ores of the Taconic. The Taconic is the chief iron-bearing formation of the Northwest. It is the "Huronian" iron-group of the Marquette region, the Penokee-Gogebic range in Wisconsin, and the non-titanic ores of the Mesabi range in Minnesota. The writer is not familiar with the Menominee iron district in Michigan and Wisconsin, but the described characters and the parallelisms that have been claimed of the Menominee rocks by Brooks, Rominger and Irving, with those at Negaunee, sufficiently show that, as claimed by Emmons and Houghton in 1846, the Menominee rocks are also of the Taconic.* The numerous important iron-ore deposits that have long been known, and formerly extensively exploited in eastern New York and western Vermont, Massachusetts and Connecticut, embracing hematite and limonite, often manganesic, afford parallels with the iron-ore deposits of the Northwest that are here classed in the Taconic. Some of the descriptions of the ore-pits of Washington, St. Lawrence and Dutchess counties, of eastern New York, recorded by Mather and Emmons in their reports on the geology of those counties are applicable, in many respects, to those of the Penokee-Gogebic and the Mesabi ranges in the Northwest.

The Granular Quartz. As used here the term Taconic does not embrace the "Granular Quartz," of Emmons, as there is sufficient evidence, in the writer's opinion, for making that the parallel of the true Potsdam of New York state.* The chief reasons for this separation may be given.

---

*Agriculture of New York, 1846, Vol. I, p. 101.

(a) *The stratigraphic relations of the Granular Quartz and the Potsdam of N. Y. are the same.* In the first place they are seen to lie unconformably on the older "granite," one on the west flank of the Green mountains, and the other on the northern and eastern flanks of the Adirondacks; and in the second place they bear the same relation to the Red sandrock of Vermont. By Dr. Emmons the Red sandrock was regarded the equivalent of the Potsdam and Calciferous sandrock, but it is described by the Canadian and Vermont geologists as Potsdam. Emmons, Logan, Hitchcock and Marcou agree in making it unconformable on the underlying slates,† but Mr. Walcott fails to find the unconformity at the point described by Marcou.‡

It seems, however, that the preponderance of evidence is in favor of such unconformity, especially when it is further considered in its agreement with observations supposed to be at the same stratigraphic horizon in the Northwest and in the Black Hills. The Potsdam is therefore here the Red sandrock, and unconformable on older slates. But by the discovery of the same fauna in the Granular Quartz and in the Red sandrock Mr. Walcott has shown that these are stratigraphically the same formation. Therefore the Granular Quartz must lie unconformably on other terranes than the "Primary" of the Green mountains.

(b) *While the fossils of the Granular Quartz are cognate with those of the Red sandrock, they are also cognate with all that have been found in the true Potsdam.* They are, however, essentially different from those of the so-called Potsdam of the Mississippi valley. This need not be amplified. It is based on one of the cardinal distinctions that subdivide the primordial fauna.

(c) *The Red sandrock overlying the Georgia group unconformably, as already stated, the Granular Quartz and the Potsdam must have the same stratigraphic position.* While this has not been observed in New York and Vermont (or when so seen the overlying strata were considered to belong to the Red sandrock) it has been observed to be the relation subsisting between an identical quartzyte in the area of the original Huronian, in northern

---

* Bull. No. 30, U. S. Geol. Sur. p. 18.

† Geology of Vermont, Vol. I, pp. 260, 317. The Taconic of Georgia and the report on the geology of Vermont, *Mem. Boston Soc. Nat. Hist., Vol. IV.*

‡ American Geologist, March, 1888. A great primordial quartzyte.

Michigan, and in northeastern Minnesota, and a series of slates underlying. In other words; The Thessalon quartzyte of the Huronian overlies (probably) unconformably the Plummer argillytes. The Pewabic quartzyte and the Wanswaugoning quartzyte overlie the Animike in northern Minnesota, but the exact contact has not yet been observed; while in the Marquette region the "quartzyte group" of Rominger overlies unconformably his "iron group."*

If we carry the comparison further:—

(d) *The stratigraphic relations of the Granular Quartz and Potsdam to the "granite" are the same as those of a great primordial quartzyte of the Northwest to the "granite."* This western quartzyte has been designated, not only Potsdam, but Sioux quartzyte, Baraboo quartzyte, New Ulm quartzyte, Barron county quartzyte, Wanswaugoning quartzyte, as well as Pewabic quartzyte, and in numerous instances it has been observed to lie unconformably on the granite supposed to be of Laurentian age.

This comparison could be extended to include the Black Hills of Dakota and the primordial section of Nevada, and it would appear that the relations here pointed out for this quartzyte are of wide application and mark it as a formation of continental extent.

(e) By Mather, Rogers, and others who have opposed the Taconic system the Granular Quartz was referred to the Potsdam sandstone.

These considerations seem to justify the conclusion that, contrary to the opinion of Dr. Emmons, the Granular Quartz should be placed at the top instead of at the bottom of the Taconic system, and that the Taconic black slate underlies it unconformably. This does not disturb his general idea that the Taconic is a sub-Potsdam formation, even using the term Potsdam in its original sense as here defined. It is, furthermore, in accordance with the views of the Swedish geologists to find the quartzyte (Paradoxides) horizon, lying above the Olenellus beds, and indicates that the Braintree (Mass.) quartzytes overlie the Braintree slates.

[NOTE.—The only intimation that the writer has been able to find that the Granular Quartz and the Red sandrock had ever been regarded the same formation by the early geologists is a statement in the "Geology of Vermont," Vol. I, 1861 (issued in 1862, Walcott), p. 346. It is by Dr. Edward Hitchcock, and in the following words: "A narrow strip of impure limestone partially separates the quartz rock from the Red sandrock in Monkton. The limestone gradually thins out, and is finally lost, so that the quartz rock and the sandrock unite with each other; and probably the line of junction is only a line separating different degrees of metamorphic action upon the same formation;" but by different geologists both the Potsdam and the Granular Quartz have, on what seemed good evidence, at different times been regarded as the equivalent of the Red sandrock. Some confusion has arisen, as it seems, in the use of the word Potsdam, by the geologists who have examined the Champlain valley in the same manner as in the Mississippi valley.* Some have applied the term to the great quartzyte (the "Granular Quartz" in its different positions) and some to the later, looser sandrock, and Calciferous sandrock, that lie unconformably on the quartzyte, and some to both varieties. The former is the horizon of the Paradoxides fauna, from New England to Minnesota, and the latter is the horizon of the Dicellocephalus fauna. It will require a re-examination of the "sandstone of Potsdam," at the typical locality, to determine the question — which is the true Potsdam sandstone ?]

---

*Sixteenth report of the Minnesota survey, pp. 45, 46.

The age of the Potsdam.

Equivalent names. Under this heading are included here several local designations which have been applied by geologists to a formation that extends widely over the United States and Canada, the uniform characters of which, as well as its fossils and stratigraphy, indicate that they all belong to one great quartzyte horizon. Some of these various names are: Granular Quartz, Red sandrock, Thessalon quartzyte (of the original Huronian), Teal lake quartzyte, No. 3, or quartzyte group (of Dr. Rominger), Baraboo quartzyte, Wanswaugoning quartzyte, Pewabic quartzyte, Sioux quartzyte. Further east, it may be represented by the quartzyte at Braintree, Mass., and the Paradoxides beds of Newfoundland. Further west it seems to exist in the Mt. Stephen section, and contains the fauna of the Bow River group, and of the "Prospect Mountain" quartzyte. It is unquestionably found in the Black Hills, but fortunately it has not there received a special name, but is embraced under the term Potsdam. This is essentially the horizon of the Paradoxides strata of the primordial.

Unconformable on the Taconic. It has been stated that this quartzyte is unconformable on the Taconic. This is sufficiently established in Vermont, in Michigan, Wisconsin and in the

---

* Emmons noticed the difference of lithology, but not the unconformity of stratification. *Geol. of N. Y.*, Vol. II, 1842, p. 269.

Dr. Edward Hitchcock seems to have figured this unconformity in Vol. I, p. 265, of the *Geology of Vermont*, but he considered the "quartz rock" here to belong to the Laurentian. At Chazy Mr. Jules Marcou states that he observed an unconformity between the Potsdam and the Chazy strata, the divergence of dip being 15 degrees.—*The Taconic system and its position in stratigraphic geology.* Proc. Am. Acad. Arts & Sci., Vol. XII, p. 190.

Black Hills of South Dakota. It is presumably so in the area of the original Huronian.* Such a widespread non-conformity indicates that the Taconic was closed by a widespread epoch of disturbance. Since the Potsdam is carried over the edges of the Taconic, and in many places is brought into contact with the "granite," which may be supposed to be older than either, it is evident that this disturbance was followed by a still further inroad of the oceanic waters on the land area of the continent. This submergence has effectually hid the Taconic formation from sight over very extensive areas, and led the geologists who saw the Potsdam lying on the Primary, in New York, to question the possibility of a formation several thousand feet in thickness belonging between them. It also produced a conglomeritic composition in the bottom of the Potsdam at nearly all places where the bottom beds have been seen.

Further evidence of disturbance during the Potsdam. The gradual or paroxysmal sinking of portions of the continent below the ocean during the Potsdam age was accompanied by other evidences of disturbance that have remained undeniable witnesses to this day. There were both basic and acid eruptions of great volumes of molten rock, which in some cases were interbedded in the Potsdam, and in others are found overlying it. These molten rocks are found generally to lie on the Taconic and the Potsdam both, but their date of outflow is fixed later than the beginning of the Potsdam by their stratigraphic relation to the Potsdam. Beds of gabbro are evenly spread with quartzyte strata above and below them, in the Pewabic quartzyte in northeastern Minnesota. In general the gabbro lies on the Animike (Taconic) in Minnesota, but a favorable observation made at Chub (Akeley) lake† demonstrates that this quartzyte was partially deposited over the Animike before the great gabbro flood occurred. The usual immediate overlie of the gabbro on the beds of the Taconic, is due to the fact that those beds were nearer adjacent at the points of issue of the molten rock. It also lies on the Keewatin as well as on the Laurentian; while the Potsdam is overwhelmed and nearly lost by the great mass of lava that issued from the interior of the earth during the time of its deposition. While the gabbro outflow seems to have been the most voluminous and remarkable in Minnesota, and to have been the earliest of the basic Potsdam eruptions, in the area of the original Huronian the Thessalon quartzyte is generally cut by and buried under an eruptive of a slightly different kind, more resembling some of the "traps" of the later epoch. There is reason to suppose this may be due to one of two causes. 1st. That at the time of the gabbro flood in other regions the area of the original Huronian was exempt (or nearly so)[*] from eruptive disturbance, and that the later basic outflows took place there after the region was elevated above the ocean; or 2nd. That while typical gabbro rock was being extravasated in Minnesota, and in some other portions of the country, a slightly different basic eruption was taking place in the area of the original Huronian. From the fact that some gabbro rock is found in the region of the original Huronian, it appears that the former of these hypotheses is more probably correct, and that there as well as in northeastern Minnesota, the basic diabase and finer trap-rock characteristic of the most of the Kewenawan, were of somewhat later date than the gabbro. That these darker, diabase traps issued at some date after the gabbro flood, is evinced not only by the dikes of the former that cut the latter, but also by the remarkable puddingstones of gabbro that are formed by the inclosure of isolated, transported masses within the diabasic sheets,[†] seen in the vicinity of Beaver Bay.

---

* In the St. Louis valley, near Thomson, the basal conglomerate of the Potsdam is unconformable on the Thomson (Taconic) slates. Tenth Minnesota report, p. 33.

† Sixteenth report, pp. 85 and 87.

This basic eruption characterizes this geological horizon throughout its extent in Minnesota, but toward the east it seems not to have been so characteristic. It prevailed in some parts of Canada[‡], and disturbances in the so-called "Quebec group" appear to involve this horizon of rocks. The Adirondack region has not been examined except about its margin. It is believed that this quartzyte exists in many places involved with the gabbro rocks of those hills. Its outcrops about the flanks of these hills have been described at places where most accessible and named Potsdam sandstone. These descriptions are applicable to this quartzyte in Minnesota—even to the vitrified surfaces that are so common in the west,[§] and which are not known to have been seen on any other formation though exposed in similar circumstances.

---

[*] One small knob of gabbro was seen near Otter Tail village. Compare 16th report, p. 29.

[†] Norwood, in Owen's report on Iowa, Wisconsin and Minnesota, p. 366; also Ninth Rep. Minn. Sur, pp. 30–31; Tenth Rep. Minn. Sur., pp. 112–118.

[‡] Geology of Canada, 1863, p. 488, 865, 875, 879; Geology of New York, 1843, Mather. Part I, p. 444.

[§] Geology of Minnesota, Vol. II, 1888, page 516, foot note. Geology of New York; Second district, Emmons; p. 269.

Post-gabbro eruptions of the Potsdam age. It has been difficult to affirm, until recently, the age of the gabbro outflow. It has generally been considered to have followed the Animike (Taconic) but that it was later than the commencement of the Potsdam was not known to the writer till he made the observations referred to above.* What were the relations of the later basic eruptions of the "Kewenawan" to the gabbro has been described by Prof. Irving and by numerous other observers. There is no reason to affirm a long lapse of time between them, sufficient to allow the formation of an oceanic terrane requiring special designation. The later eruptive rock embraced and probably transported loosened masses from the gabbro, as evinced in the "feldspar masses" described by Norwood near Beaver Bay on the north shore of lake Superior, and the puddingstones observed by the writer. But this, rather than indicating a long intervening time, seems to imply a quick succession in the eruptions, or else a continued elevation above the sea so as to prevent the accumulation of intervening sediments. That there was no exemption from sedimentation after the gabbro is shown by, (1) the absence of any sign of ancient land surface, (2) by the continued and frequent interbedding of eruptive and sedimentary rocks through the entire Kewenawan (Geol. of Wis. Vol. III, p. 403), and (3) by the gradual transition of the basal conglomerate of the Potsdam, in favorable places, from a siliceous, or pebbly-quartzose, character, through a siliceous sandrock to a feldspathic sandrock, and to a pebbly volcanic tuff. Such transitions are frequent on the north shore of lake. Superior. One of the most important observations was recorded in 1879,† when the basal quartzose conglomerate of the Potsdam was found, dipping in consonance with the shales and tufaceous conglomerates of the overlying Kewenawan, in the St. Louis valley, unconformable over the Thomson slates, and embracing lenticular spots of shaly rock and red (Kewenawan) conglomerate as constituent and conformable parts of itself. This shows a conformable, though somewhat intermittent, course of sedimentation from the basal conglomerate into the typical detritus of the overlying beds of the Kewenawan; the interruptions and the changes in the nature of the sedimentation being attributable to the eruptive disturbances that took place in the adjoining regions. It will be seen at once that this links the Kewenawan to the gabbro, and both to the Potsdam.

---

*Sixteenth annual report, pp. 85 and 88.

†Tenth report, pp. 11, 32, 33.

Acid eruptions during the Potsdam. The dynamic forces that operated to bring molten basic rock to the surface of the earth in northeastern Minnesota also softened the acidic strata of the super-crust, which in some places seems to have culminated in the molten protrusions and lateral displacements of large masses. These acid eruptions, ranging from felsitic to granitic, are of limited amounts in Minnesota and Wisconsin. Sometimes they are in contact with the Taconic strata as at Duluth (10th Rep. p. 108), sometimes with the Potsdam,* and sometimes with the basic eruptions of the Potsdam.† They are seen in contact with the Taconic slates of the original Huronian (16th Report), and there seem to be the direct result of change from some sedimentary, siliceous strata.

Whether this feature of the Potsdam is persistent through eastern Canada, and in New England, is uncertain, owing to the prevalence of definite "Laurentian" theories as to the age of most of the granitic rock that geologists have studied in that part of the country. There is, however, every reason to affirm a widespread and profound volcanic disturbance, extending from the Black Hills, at least, to Vermont and eastern Canada, that began in the Potsdam era and closed with that era, and that some of its results in the forms of acid as well as basic eruptive rock, as mentioned above for the Northwest, must characterize this formation in New England, there is good reason to expect. Indeed some descriptions of such phenomena have been published. Dr. Hitchcock mentions some Potsdam schists that contain "veins of granite whose feldspar is labradorite" (Geol. of Vermont, Vol. I, p. 264). There are many instances published where the slates of the Taconic including the granular quartz are so placed as to run beneath masses of granitic rock, but such a possibility has been negatived promptly by resort to that easy hypothesis of a fault, to bring up the "Laurentian." Dr. Emmons describes such instances.‡ Similar facts have been mentioned by Prof. C. H. Hitchcock§ in New Hampshire, although there is no certainty that the slates described by him are of the age of the Taconic. Prof. Hitchcock makes it very apparent that the granites of New England cannot all be placed in the Laurentian any more than they can in Minnesota.

---

*Geology of Wisconsin, Vol. II, pp. 251, 506, 522.

†Tenth Minnesota report, p. 110.

‡Geology of New York: Second district, 1842, pp. 141, 145, 159. Agriculture of New York 1846, Vol. I, pp. 63, 94.

§American Geologist, April, 1889, p. 254. Geology of New Hampshire.

The Potsdam age closed, therefore, with the cessation of the disturbances and volcanic eruptions which introduced it. The beds that were formed were left in upturned and fractured attitudes for the attacks of the succeeding St. Croix age. These strata embraced not only the basal quartzyte of the Potsdam, but the gabbro, and all the succeeding eruptions that are found in the Keweenawan. Here would necessarily appear a marked and extended plane of unconformity, and this fact, when sufficiently recognized, will be found to distinguish the rocks at many places — whether Potsdam or St. Croix — and be a criterion by which to judge of their stratigraphic place in the geological column. In other words, the Potsdam is unconformable on the older gneiss and slates and schists, and is cut and covered by eruptions of the same age as itself. It would not normally be found unconformable on rocks of its own age over wide areas, although contemporaneous disturbance might certainly produce local non-conformity. The later formations may show non-conformity over wide areas of the rocks of the Potsdam, and such we find to be the fact.

The age of the St. Croix sandstone.

That it may be made plain to the reader just what strata are considered by the writer the Potsdam sandstone, this history may be carried one step further. This is the more necessary inasmuch as some of the steps in the history which are well known in the Northwest, have not yet been recognized, or have not been admitted as facts, by most of those who have examined the geology of the Champlain valley. It appears that a very widespread succession of physical changes affected the lower paleozoic and crystalline terranes in America with a uniformity of effect that is surprising, and which leads to very serious questioning of the doctrine that formations can not be recognized by their lithology from place to place because of the liability to physical change. There is, in fact, a remarkable persistence of lithologic characters, and of stratigraphic relationship, between Minnesota and New England. The satisfactory establishment of some points in the geology of the Northwest throws much light on moot points in the geology of the east. While most of these coincidences and identities have to be reserved to a later discussion, one of the most interesting concerns immediately the formation which is under consideration — the *St. Croix sandstone* of the Mississippi valley, and its relation to the Potsdam.

The separateness of the St. Croix from the Potsdam. It has already been stated that some confusion has been introduced by the use of the term Potsdam by different writers in different senses. This began with the early descriptions of the geology of eastern New York, Vermont and Canada. This confusion was one of the most obtrusive problems that confronted the writer in 1872 in the preparation of his first annual report. In order that a more definite understanding might attach to whatever he should be called on to publish respecting this horizon he chose to designate the lower formation Potsdam and the upper one St. Croix, and this distinction has been observed in the later publications. If not correct it has at least served to give definiteness to all his descriptions.

This problem was given pointedness a short time prior to the beginning of the Minnesota survey by the writings of Prof. R. D. Irving, who had shown that in Wisconsin the upper formasion was unconformable on the lower.* Irving's papers on the Wisconsin quartzytes proved the existence of two formations in places where hitherto, by some, there had been supposed to be but one, and, assuming the upper, or horizontal, beds to be the Potsdam, based on the conjectures of Prof. James Hall published in the Sixteenth (N. Y.) Regents' report, he announced the upper one to be the equivalent of the New York formation and the lower one he relegated to the "Huronian," that convenient limbo to which it has been customary to consign uncertain stragglers from the upper "Silurian" and from the nether "Laurentian." It was not presumed at that time that the geology of the Northwest would be found to tally closely with that of New York, and as there was no mention of such a great "Huronian" quartzyte there, nor in New England, the presumption was that the "Huronian" was a formation that affected Canada and the Northwest, and that, therefore, this great northwestern quartzyte would not be found further east than the northern shore of lake Huron. Only the "Potsdam" was described in eastern New York.

Upon pushing the distinction further east, however, and upon making a wide study of the older terranes, which, when better understood, are found to exhibit a surprising concord of essential features with those of more eastern as well as western regions, it is found that there is every reason to believe, not only that there exists the same great underlying quartzyte in New England and eastern New York, but that there are unmistakable evidences of the same non-conformity between it and the overlying horizontal, or nearly horizontal, beds. Moreover, it is equally plain, on making an examination of descriptions that have been published by the eastern geologists, that both the formations have been with great positiveness called Potsdam sandstone. It is very evident that no little misunderstanding has resulted from a failure to observe and acknowledge this important line of non-conformity. But wherever it has confronted the geologist in Vermont or eastern New York, it has been glided over indifferently or has been accounted for by some outre hypothesis, such as "overturn" or "fault," or temporary "non-deposition," or "metamorphism from contact with the Primary."

---

* Am. Jour. Sci., Feb., 1872; April, 1872.

In order to support this statement some references will be made to the published descriptions of the "Potsdam" in New York. No reference will be made to the Granular Quartz nor the Red sandstone, both of which the writer believes, as the reader will have observed, are identically and only, the Potsdam formation; but to some statements concerning the "Potsdam sandstone" as understood by the geologists who made them.

Emmons. In his report on the geology of the Second District, 1842, Dr. Emmons uses these words in describing the Potsdam in Essex county—"In consequence of this rock presenting two quite distinct varieties, and those varieties being well developed, the one at Potsdam, St. Lawrence county, and the other at Keeseville, I have sometimes given it a compound name—the *Potsdam and Keeseville sandstone;* for the reason that at the former place a beautiful granular variety, and at the latter a harder and more crystalline mass predominates, which resembles the granular quartz of the Taconic system." Near Keeseville the rock that outcrops he describes as exhibiting some interesting changes upon the surface of the layers, presenting "a smooth and semi-vitreous surface—a kind of glazing;" by which he seems to have meant the same polished or glazed surface that appears frequently on the Potsdam in Minnesota. It is plain, therefore, that Emmons noted the contrasting lithology, but, so far as the writer has observed, he did not recognize any unconformity in the "Potsdam," or between it and the Calciferous.

E. Hitchcock. There is not much doubt that Dr. Hitchcock noted exactly an unconformity between the two formations at West Haven (Geol. Vermont, Vol. I, p. 265), but he regarded the lower one as a part of the "Laurentian," and the upper as the Potsdam. He states that "the only way of distinguishing the Laurentian character of the [lower] deposit is by the higher dip of its strata, upon which the Potsdam sandstone rests unconformably. A section passing across the south end of West Haven, in fig. 168, represents the unconformable relations of the Laurentian rocks and the Potsdam sandstone to each other. Were it not for this discordance in the stratification we should regard the lower rock as Silurian because it does not differ lithologically from the sandstone above. But in following the strata northwardly the quartz rock becomes more gneissoid. Some of the specimens in the cabinet are very distinct gneiss, one of them with the labradorite, the characteristic species of the feldspar of the Laurentian series."

Let the reader compare the description of the "quartz rocks" of the Laurentian with the following description of the "Potsdam" *at the same place.*

"The third variety very closely resembles the Laurentian gneiss. It seems to pass into it by insensible gradations. The specimens obtained are from the southwest part of West Haven. All the constituents of this rock are very small, and occasionally the feldspar or the mica may be wanting * * * Associated with these crystalline schists are veins of granite, whose feldspar is labradorite. This mineral is mostly confined to rocks below the Silurian system; and in West Haven it extends only a few feet into the base of the Silurian, and that in small veins from three to ten inches wide.

"The unconformability of the dip of this rock to the Laurentian beneath [sic] may be seen at the extreme southern point of West Haven. Upon the lake, opposite the termination of the railroad the dip of the older rock is 36° East, and only a few rods east the dip of the sandstone is only 9° East. As the south part of West Haven terminates in a cliff this section can be seen distinctly from quite a distance. The rock with the greater dip is as distinctly quartz rock as the other, and there is also a large ledge of quartz rock upon the west side of lake Champlain with the same inclination. Hence the sudden change in the dip is to be regarded as a safer distinction between the Silurian and Laurentian series than a difference in lithological character."

Setting aside Dr. Hitchcock's identification, either of the following interpretations of the facts, in the light of what has since been learned of the geology of the Taconic and the granular quartz, would be possible. (1) The lower rock is the Potsdam (granular quartz) and the upper is the St. Croix; or (2) The supposed unconformity is only an illusive appearance in the same formation, perhaps false bedding, or oblique stratification, or a sheeted disintegration which sometimes is superinduced by weathering even in the firmest crystalline rocks. In the light of further considerations the latter explanation seems most probable.

(a) Prof. C. B. Adams had stated in his first annual report that the Potsdam sandstone only reached within half a mile of the state line near Whitehall, and did not enumerate it at all in his table of Vermont formations.* If this were true it would be necessary to consider this West Haven quartzyte as the Red sandrock or the granular quartz. Either of these explanations, to so strong an opponent of the Taconic as Hitchcock was at that time,† would be avoided if possible. For, to class it as a part of the Red sandrock spur that shoots southward from the town of Monkton, the last remnant of which his map represents on the south line of Orwell, bearing in a direction toward West Haven, only seventeen miles distant, would be to bring the "Medina sandstone" below the Calciferous which exists in the immediate vicinity and into contact with the Laurentian; which would necessitate the abandonment of the "metamorphic" idea that the Red sandrock and all the Taconic rocks were changed conditions of the Lower and Upper Silurian of the Champlain system of New York. Also, to admit that it is an outcrop of the Granular Quartz of Dr. Emmons, would in like manner bring the Granular Quartz beneath the Calciferous and even unconformably beneath another sandstone that might be the Potsdam; this would substantially confirm everything that Emmons claimed for his Taconic. These alternatives were clumsily obviated by introducing the Laurentian. That this "Laurentian" is the gabbro of the Potsdam age is probable from the nature of the feldspar which it is said to contain.

---

*First annual report, Geology of Vermont, 1845, p. 61.

†It is evident that a change of opinion was accomplished in Dr. Hitchcock's mind during the preparations of this report. This is intimated in Vol. I, p. 435.

W. W. Mather. So far as discoverable all the descriptions of Potsdam by Prof. Mather* apply to the lower or quartzyte division. He notes repeatedly his belief that the Granular Quartz is a metamorphic condition of the Potsdam.

L. Vanuxem distinctly mentions the same varieties of rock in the Potsdam as Dr. Emmons, and employs the double designation "Potsdam and Keeseville sandstone," but he mentions no unconformity. He intimates, however, that the Potsdam, in its loose-textured variety, is with difficulty distinguished from the Calciferous sandrock. The latter he describes at numerous places in immediate contact on the primary.

Sir Wm. Logan. In the *Geology of Canada*, 1863, this formation is amplified into "Potsdam group," and includes a thickness, on the St. Lawrence river, of 540 feet. This group embraces not only the true Potsdam but several beds of conglomerate, white sandstone suitable for glassmaking, fucoidal beds, limestones and a singular breccia like that described by Emmons at Chazy and said to separate the Potsdam from the Calciferous. The fauna which appertains to the upper layers is that characteristic of the Calciferous. It is evident that the true Potsdam is here confounded with the overlying St. Croix-Calciferous, and that the Calciferous is restricted in the words of Logan, essentially, to "a granular magnesian limestone or dolomite, which from its rough weathered surface and slight effervescence with acids may have suggested the name of Calciferous sandrock." In the annual reports the Potsdam had not been recognized about lake Huron; but the lower great quartzyte had been included, along with all the strata equivalent to the Taconic under the term Huronian. His opinion of some quartzyte beds on Murray bay which at first Logan regarded as Potsdam, and which he so described (*Geol. of Can.*, 1863, *p.* 96), he modified by adding a footnote stating that it had been ascertained by Dr. Dawson that "these quartzytes really belong to the Laurentian series."

James Hall. The Potsdam sandstone does not occur in the Fourth District, on which Mr. Hall reported, but he examined it on the north side of lake Ontario, and subsequently on lake Superior and in the Mississippi valley. His general description in the report on the Fourth District is such as would apply to the lower quartzitic portion.

In the lake Superior report of Foster & Whitney (1851) the step which was inaugurated by Logan in the creation of the

---

*Geology of New York, First District, 1843.

"Potsdam group," embracing the quartzyte and the overlying sandstone in one designation, was completed by the entire severance of the lower formation from the name, and its application only to the upper or nearly incoherent sandstones. At the same time the quartzyte, along with all the strata of the Taconic associated with it, were included in the "Azoic," embracing both the Laurentian and Huronian. This upward movement of the names of the New York formations, is shown by the following words (p. 114): "The Potsdam sandstone of New York is a quartzose rock whose particles are firmly aggregated, while the the same rock, on the northern slope of lake Michigan, is so slightly coherent, that it may be crushed in the hand. The Calciferous sandstone of New York, when traced west, passes into a magnesian limestone." This supposed change in the nature of the formations toward the west is largely imaginary; the change seems to consist rather in the transference of the original names to strata higher in the scale, and the creation of new names for the abandoned strata. All the authors of this report, including Prof. James Hall, apply the name Potsdam only to the friable sandstones which are unconformable with the Copper-bearing traps and basalts which, as already shown, are of the age of the lower quartzyte.

As to the paleontology of the Potsdam in New York, which is quite meagre if the more recent additions from the Calciferous be disregarded, an interesting problem centres on the fossils Lingula (Obolella) prima and (Lingulepis) antiqua. By Prof. Hall these are assigned to the Potsdam. In respect to L. prima it is reported at Keeseville on the authority of Dr. Emmons, and it is reported from the Mississippi valley on the St. Croix river. To the writer the St. Croix beds have been known for some years as belonging about to the horizon of the Calciferous, and they have been so parallelized by Irving.* The Calciferous, here including the magnesian limestone known as Lower Magnesian, is unconformable on the trap rock, and, in common with the sandstone underlying it, becomes conglomeritic by reason of such unconformable contact. The beds here exposed are not so low as the lower layers at Stillwater where the first specimen of Dikellocephalus was discovered by Dr. Owen. It would seem, therefore, if we can depend on the indications of paleontological evidence, that the Potsdam at Keeseville, containing Lingula prima would be considered substantially the parallel of the Calciferous beds at Taylor's Falls in the St. Croix valley. What are the facts? On re-examining Dr. Emmons' description of the sandstone on the Au Sable river in his report on Essex county, he says that this general range of sandstone, containing the Lingula prima according to Hall, *reposes against the hypersthene rock*, (i. e., the gabbro) and contains Lingula antiqua; and Prof. Hall corrects this indentification of Emmons by saying the species figured by him from this place is not L. antiqua but L. acuminata of Conrad, which is a Calciferous species, and does not occur, to his knowledge, in the Potsdam.* Therefore all the evidence from paleontology and from stratigraphy, so far as it can be gathered from the report of Emmons and the first volume of the Paleontology of New York, indicates that the beds on the St. Croix are the equivalent of those described at Keeseville, and that both belong to the Calciferous; at least that they are both later than the eruptive epoch of the Potsdam as here limited.

---

*U. S. Geol. Sur. Monogr. V. Copper-bearing rock, of lake Superior, p. 446.

This brief examination of some early descriptions of the Potsdam of New York, which might be extended to include several other names, is sufficient to prove the truth of the foregoing statement that the distinction which has been made in the Northwest could with propriety also be made in the East, and that a plane of non-conformity between the Potsdam and the Calciferous extends through eastern New York and Vermont, and that there, as in Minnesota, the upper (St. Croix) sandstone has greater affiliations with the strata that succeeded the break than with those that preceded it.

In this review it is assumed that the "sandstone at Potsdam" preceded this non-conformity. It is evident that some re-examination should be made of the region before this can be considered established. Dr. Emmons, in his section passing from Canton to Parishville (Plate ix. *Geol. of New York*) shows that *gneiss* exists at Potsdam below the sandrock, and this rock he always keeps definitely distinct from *hypersthene rock*, which he argues was elevated at a later date than the Green mountains. The parallelism of position between the Potsdam sandstone at Potsdam, and the Granular Quartz, in this respect, both lying upon the gneiss, not only indicates a possible parallelism of age, but that they are possibly older than the Keeseville sandstone which rests against the hypersthene rock.

It is further assumed, in this review, at least in making the extension of the western parallels to the east, that the gabbro of the Northwest is the chronologic analogue of the hypersthene rock of the Adirondacks. The lithology is identical, except that various "limestones" are mingled with the hypersthene rock which have not, so far as known, any parallels in the gabbro of the Northwest. This assumed parallelism may also be set down as not sufficiently established.

---

*It is put in the "Potsdam group" by Logan, Geol. of Can., 1863, p. 102.

It is also assumed that the Pewabic quartzyte of northeastern Minnesota, with which gabbro is interbedded and which lies below the great gabbro overflow, is the equivalent of the Wauswaugoning quartzyte and of the Pipestone quartzyte of the southwestern part of the state carrying a primordial fauna, which last is very certainly the equivalent of the Thessalon quartzyte of the original Huronian. Still the Pewabic quartzyte may not hold this relation to the Wauswaugoning beds; the connection has not been traced; yet they seem to be similarly situated with respect to the gabbro sheet, and are not widely separated from each other.

The writer has attempted to indicate such general equivalency as has appeared to him probable, and which embraces a greater fund of concordant fact and testimony than any other scheme of chronologic succession. He may be wrong in some parts of this history, and especially in the extension of the story as made out in Minnesota to eastern states, and holds it, in large measure, as tentative at this stage of the investigation. When facts can be found out sufficient to correct it in any way, he will be glad to welcome them, for he freely admits that there are questionable steps and missing links in the history, which have to be bridged by hypothesis and nothing else. That is, however, the nature of all investigation, and especially of all attempts to formulate any general truth.

PROBLEMS THAT NEED FURTHER INVESTIGATION.

As already stated, as this investigation has proceeded, no sooner did we surmount the difficulties which immediately beset the first attempts than new difficulties appeared. The solution of one problem seems to serve for vantage ground to behold others in the greater distance. It will be desirable to mention some of the questions that appear at present to require further study, and further field-work. This will distinguish more exactly the status of our present knowledge, or body of truth on which we rely, from the realm of hypothesis or of unfinished work and research, to which it will be necessary to devote the efforts of the survey at some future date.

Eruptive and sedimentary Laurentian. Beginning with the Laurentian, as defined above, one of the unfinished courses of study relates to the distinctions, both geographic and structural and petrographic, between the eruptive masses of syenite, or granite, and those that are supposed to have resulted from change *in situ* of the oldest sediments. This will involve the further question whether the "gneissic structure" is necessary, or even possible, in a truly eruptive rock. But first of all it will necessitate a correct definition of the term "gneissic structure."

There are three distinct ideas that have been confused under the term gneiss, or gneissic structure. No reference is made here to the use of the term gneiss as a rock species, but to the structure which is supposed to distinguish it, the proportionate amounts of the usual mineral ingredients being variable, and sometimes constituting a dark-colored, perhaps basic, rock, and at other times an acidic one. Referring only to *structure*, therefore, a rock has been said to be gneissic when *foliated;* but it is plain that there may be different kinds of foliation, (a) that lamination which consists of an undulating layered structure, the mica element not being unevenly distributed, but all the scales being parallel with the sheeting, and all the grain of the rock having a uniform structural rift which facilitates quarrying. If there be a finer lining or sheeting of the mica element the lines or sheets are not continuous far, and may be seen to fade out within a distance of a foot or two. That is to say this foliation does not indicate a profound separation of the minerals of the rock into layers or long continuous sheets. (b) A second sort of foliation is that which arises from a distinct separation of the minerals of the rock, or different proportions of the constituent minerals, into sheets or strata that continue over long distances. Such separation is indicated on the weathered surfaces by color-bands, and by petrographic differences of grain and composition. In short this foliation is plainly a modified sedimentary structure. The sheets, or layers, or strata, into which the rock is separated, are traceable over large surfaces. The crystalline condition of the grain here may be as perfect as in the last, and this constitutes the "crystalline schists;" but in many places there is seen an imperfect, or interrupted, crystallization, the various grains blending round their borders into each other, or being lost in an indefinite matrix, or developing porphyroidally. (c) Still another structure has been styled gneissic. A massive homogeneous rock, which may have neither of the foregoing kinds of foliation, but which exhibits the micaceous or hornblendic element evenly distributed in isolated individual grains throughout the whole, yet is seen to have a uniform elongation of the separate crystals, of all kinds, in the same direction. This furnishes also a kind of rift or grain which pervades the mass, rendering it easier to break in the direction parallel with the greater diameters of the crystals than in any other, but it is essentially a massive non-foliated rock. A massive structureless granite, or syenite, is rare to see. Hence by far the greater part of the Laurentian, whether eruptive or sedimentary, is properly styled gneiss. It is obvious, however, that these three structures should not all be described by a single term.

When these structures are once sufficiently differentiated in the mind of the observer, and are carefully applied in descriptions, there will still remain to ascertain what relations they separately sustain to the supposed two sorts of Laurentian rocks, i. e. whether one or the other may be found to characterize the actually eruptive acid Laurentian, or the metamorphosed sedimentary Laurentian.

Planes of hydro-thermal fusion, and their relation to the origin of the crystalline schists. A second problem connected with the Laurentian, and which appears prominently in the horizon of future research, relates to the origin of the crystalline schists.

It has been stated above that there is every evidence to suppose that the eruptive epoch which introduced the Vermilion age (i. e. the crystalline schists) continued into the Kewatin (i. e. the sericitic schists and graywackes) by an unbroken and uniform succession of events and oceanic deposits. This binds the Vermilion and the Kewatin, historically, closely together. It has been said also that the mineral characters of the Vermilion fade out very slowly into those of the Kewatin, but that when fully established the change is so great that the formations have great mineralogical contrasts. In other places the crystalline schists have a very feeble development at the horizon where they would be expected to appear, and the Kewatin graywacke-like sediments pass into the Laurentian sediments through a gradual change from graywacke to gneiss—a gneiss having the second kind of foliation described above.

The crystalline schists seem to be, nearly always, as completely crystalline as the gneiss. If the origin of the basic sediments of the crystalline schists be akin to that of the sericitic sediments of the Kewatin, viz. from volcanic ejectamenta, the query quickly arises—why are they not similar in the resulting rocks? Why are the crystalline schists so uniformly composed of the same minerals as make up gneiss, though differing from gneiss in the relative amounts of those minerals and in the evident sedimentary structure, while the Kewatin, sericitic schists are only subcrystalline and are often earthy? Is it not plausible to suppose that the crystalline schists are but a phase of the earthy Kewatin schists, due to the encroachment of hydro-thermal fusion-planes upon them? At the present time these beds all stand nearly vertical. If this fusion affected them after this verticality was attained, it may be supposed that the approach of the fusion-plane toward the surface of the earth would be nearer in some places than in others. When the fusion was accompanied by fracture more or less of the fused rock-matter would be thrust through the fissures and would appear as eruptive rock. Since there are certainly places where in the Kewatin sediments such fusion, and even such eruption, seems to have resulted from the Kewatin itself; and since in the immediate vicinity the sediments adjoining take on over a greater or less width, the characters of the crystalline schists, and at other places the crystalline schists do not appear where the Kewatin sediments exhibit that peculiar semi-crystalline condition which has been mentioned as "porphyrel," it has appeared to the writer that very likely the crystalline schists have no constant stratigraphic place, any more than the Laurentian gneiss, and that the "crystalline" phase has been superinduced *in situ* on basic (or acid) sediments in strata of different ages, according as, after being deposited, and even after being tilted to verticality, the level of hydro-thermal fusion was able to reach them or not. Therefore, without any undulating of the actual strata in anticlinal and synclinal folds (a supposition which seems to be precluded in some places by the extensive present vertical position of all the strata), there still might result, superficially, successive belts of rocks of different kinds. The belts would express the effects of hydro-thermal fusion, perhaps on the same sort of sediments, in different degrees of intensity. Wherever erosion and denudation may have been sufficient to bring the present surface down to the level where the fusion-plane operated in its full intensity, there we should find the present surface rock to be gneiss if the sediments were acidic, crystalline schist if the sediments were partially basic and stratiform, or eruptive rock if there were fissures through which such could and did escape. Where the surface erosion has not been sufficient to expose the upward (or the downward) undulations in the plane of perfect fusion, we find the earthy, or volcanic, or siliceous, sediments more nearly in their original condition.

Date of upheaval of the crystalline schists. Intimately connected with the question of the origin of the crystalline schists is the question of their date relative to the epoch of their upheaval, and the further, or prior, question as to the cause of the very general and extensive verticality of all the sedimentary strata that precede the Taconic (Huronian).

Nature and origin of jaspilyte. Attention has been called to some points in the investigation of this question which need further examination.

What is the "muscovado rock?" and, particularly, does it represent a sedimentary formation younger than the Kawishiwin and older than the Taconic.

COMPARISON OF THESE RESULTS WITH THOSE REACHED ELSEWHERE.

Following is a tabulated statement of the general stratigraphy supposed to exist in Minnesota, according to the foregoing sketch.

Calciferous. Magnesian limestones and sandstones.......................................} Dikelocephalus horizon.
St. Croix. Sandstones and shales...........}

Overlap unconformity.

Potsdam. Quartzyte, gabbro, red granite and Kewenawan............Paradoxides horizon.

Overlap unconformity.

Taconic. Black and gray slates and quartzytes, iron ore, (Huronian, Animike)........................ ....Olenellus horizon.

Overlap unconformity.

Kewatin (including the Kawishiwin or greenstone belt, with its jaspilyte), Sericitic schists and graywackes.................. }
Vermilion (Coutchiching), crystalline schists } Archean.
Eruptive unconformity. }
Laurentian. Gneiss...... .... }

Comparing this with the results reached by the late Wisconsin survey, it is found to differ considerably from the table of formations published by Prof. Irving, in the third volume of the final report of that survey, pp. 92 to 211. Prof. Irving describes the Laurentian as composed of "dark-colored and altered (chloritic) hornblende-gneisses and pink quartzose granites." These he considers very evidently originally clastic rocks, without any recognizable eruptive portions, and to lie unconformably below the Huronian. The last he divides into twenty-one parts, in the same manner as major Brooks, in his report on the geology of Michigan. The aggregate thickness is supposed to be about 12,800 feet. But in this thickness he includes all the strata from his Laurentian to his Kewenawan, viz. in descending order:

XXI. Mica schist, with intrusive granite.
XX. Probably mica schist, like XXI.
XIX. Greenstone schist.
XVIII to XV. Alternations of black mica-slate and dark gray quartzyte, or quartz schist.
XIV. Black mica-slate. This and the last are carbonaceous.
XIII. Chloritic dioryte.
XII. Black magnetitic mica-slate.
XI. Probably mica-slates.
X. Mica-slate.
IX. Chlorite dioryte.
VIII. Probably mica-slate, like VII.
VII. Mica-slate.
VI. "Peculiar hornblende rock," containing also quartz, apatite, milky orthoclase and rare plagioclase; also biotite, cut by pinkish, coarse, granite veins.
V. Black feldspathic slate, carbonaceous.
IV. The magnetic belt; made up of banded magnetitic quartzyte, magnetitic quartzyte, magnetitic quartz-slate, actinolitic magnetitic quartz-slate, arenaceous to compact and flaky quartzyte, thin-laminated, soft, black, magnetitic slate, hematitic quartzyte, garnetiferous actinolite-schist or eclogite schist, and dioryte.
III. Siliceous slate or schist, a light-gray, soft, mica-schist, sometimes a fine quartzyte.
II. Arenaceous quartzyte.
I. Crystalline limestone.

For greater details respecting these parts the reader is referred to Vol. III, Wisconsin geological report, pp. 106–166.

The Kewenawan system Prof. Irving here describes as consisting of a "lower division, embracing chiefly great flows of gabbro, diabase, and melaphyr, and an upper division composed chiefly of reddish feldspathic sandstone, subordinate to which are heavy beds of boulder-conglomerate, indurated gray and brown quartzless sandstone and black shale." Among its eruptive rocks he includes gabbro, diabase and diabase amygdaloid, melaphyr, granite and porphyry, the last being possibly clastic. Among its fragmental he notes boulder-conglomerate, black and gray shales, gray and brown quartzless sandstone and red sandstone and shale.

Unconformable over the last he places the light-colored "lake Superior or Potsdam sandstone," which he considers either the "equivalent or downward extension of the Potsdam sandstone series of the Mississippi valley."

It is evident that in this description there is included nothing that answers to the Kewatin and Kawishiwin. It appears that a feeble representation of the crystalline schists is noted in connection with the Laurentian, as "dark hornblende gneisses." Essentially all of these parts, from No. I to No. XX inclusive, are the Animike of northeastern Minnesota, the real Huronian without the overlying Thessalon quartzyte. According to observations already recorded this overlying unconformable quartzyte is in northern Minnesota interbedded with gabbro sheets, and the great gabbro flood lies on the lower portions of it. It is a natural inference that in an epoch of successive volcanic eruption like that which followed the gabbro outflow, a quartzyte would locally lose its typical character, and would be converted to feldspathic sandstones, conglomerates and shales, and that these would be interbedded with the eruptive sheets. Such seems to have been the case in northern Wisconsin and in northeastern Minnesota within the area affected by this remarkable series of eruptions. But in central Wisconsin, as well as in southern Minnesota, and in S. Dakota, the normal conditions again prevailed, and a similar quartzyte is found to exist, repeating the sedimentary succession that obtains in the area of the original Huronian.

The peculiar "mica schists" cut by intrusive granite, represented to overlie all the rest of the Huronian, seem not to have been identified in Minnesota. There is, in connection with the gabbro, in northeastern Minnesota a large amount of red granite, passing to felsyte such as that seen at the *Great Palisades*, on the north shore of lake Superior. It is possible that in connection with this granite will yet be found some micaceous schists answering to these in Wisconsin, the result of metamorphism from some of the Animike beds.

Prof. Charles E. Wright and major T. B. Brooks, who report, in the same volume, on some of the crystalline rocks of Wisconsin, present substantially the same classification. But they distinctly include the "crystalline schists" in the Laurentian. Brooks, who made out this order first in the Marquette region, and gave the parts similar numerical designations, groups them in three principal parts, viz.:

Upper Huronian, Beds XIV to XX.

Mica slates, mica schists, granites and gneisses.

Middle Huronian, Beds VIII to XIII.

Quartzytes, clay slates and obscure soft schists.

Lower Huronian, Beds I to VII.

Quartzyte, marble, iron ore, novaculite.

Brook's stratigraphic scheme is subject to criticism, and is ambiguous and certainly incomplete, although for a pioneer attempt to set the stratigraphy of the region of Marquette into a semblance of chronological succession it deserves great praise, for it supplies the first general classification and gives form to a tangled mass of variant and unfinished observations and isolated facts that had been published before. Since the examinations made by Brooks the whole country has been much cleared up, many new openings have been made and the geology is much easier to ascertain with certainty than ever before. Dr. C. Rominger, in a later survey, was aided by some of these advantages, and in some instances he was enabled to correct the stratigraphic scheme of major Brooks. His report, however, is, as it professes to be, mainly a description of facts, without much effort to decipher the stratigraphy.

Dr. Rominger hesitated about placing the granitic rocks of the Marquette district as the parallel of the Laurentian of Canada, although he regards the rest of the series, with some noteworthy differences, as the Huronian. He rejects the twenty subdivisions made by Brooks, as altogether too numerous and somewhat vague, and some of them he omits from the succession, regarding them as intrusive masses belonging really to lower horizons. The two quartzyte members, of Brooks, he considers but one. With slight exceptions Dr. Rominger's descriptions and classification are in accord with the general stratigraphy and all the geology of the Northwest as now held by the writer. Those exceptions consist, principally, in dividing the strata concerned into two distinct formations, separated by a plane of unconformity which exists everywhere and is observable (and has also been mentioned many times by him), in the iron regions of both Minnesota and Michigan. Brooks paid but very little attention to the rocks embraced by Rominger in his serpentine and dioritic groups. But these constitute, in accordance with the conclusions of this report, the basement floor on which the true iron-bearing formation makes an unconformable overlap succession, and are the southern representatives of the sericitic and chloritic schists and graywackes of the Kewatin. Another important difference concerns the great quartzyte of the Marquette region. Dr. Rominger considers it a constituent part of the conformable strata of the Huronian. I think sufficient evidence exists for removing it from the system that embraces the ore beds, and placing it as an unconformable overlying stratum, the equivalent, nevertheless, of the great upper quartzyte member of the original Huronian. Again, the arenaceous slate group, and the iron group, appear to the writer to be, if not identical, very closely associated members of the grand series, and not worthy of separate designation. One may overlie the other, in general, but they probably graduate into each other lithologically and stratigraphically.

In making comparisons, however, the most interesting are found to subsist between this work and that of Mr. A. C. Lawson, of the Canadian survey. In the examination of the geology of the Lake of the Woods Mr. Lawson encountered a series of rocks, which, while included by his predecessors in the Huronian, differed markedly from the descriptions of the original rocks of the Huronian as published by the Canadian survey, and he gave them the name which is used by the Minnesota survey,—the "Keewatin." These he inferred to lieun conformably below the Animike, found further southeast, and they were subsequently traced continuously to the north side of Gunflint lake, and found to become there the very same strata which the Minnesota survey had already described as unconformable below the Animike, but which, however, were not fully wrought out by the Minnesota survey, nor identified as different from the Huronian. In the later prosecution of the work in Minnesota this widespread unconformity has been fully recognized, and the separateness of the strata above it from those below has been established beyond all question.

A still further interesting parallel between the work of the Minnesota survey and that of Mr. Lawson consists in the separation of the crystalline schists from the Kewatin, under a distinct name, and the recognition of some (at least local) unconformity due to eruptive action between them and the Laurentian gneiss. Mr. Lawson gave them the name Coutchiching, not including in them the basic eruptive rock associated at this horizon, and this survey, about the same time applied to them the name Vermilion, but included in them all the eruptive basic rock which appeared to grade off into dark and hornblendic schists and to micaceous schists. By Mr. Lawson this eruptive belt is considered as of later date than the schists, and perhaps as late as the Kewenawan, but by the writer it is regarded, so far as seen in Minnesota, as having actually preceded the crystalline schists, and really to be the most obtrusive agent in the introduction of the lithology that characterizes the crystalline schists. The principal eruptive rock was the acid Laurentian gneiss, according to Lawson, but according to this survey it was the basic doleryte.

There are minor differences, such as that touching the eruptive nature of gneisses, the later date of the Laurentian, the character of the thin, interleaved, gneissic strata between thin sheets of mica schists, sometimes reaching 100 or more alternations, and others, which will furnish subjects for future research. But the general concord, in the main results, between the conclusions of Mr. Lawson, and those expressed already, in this report, on the succession of the principal steps in Archean stratigraphy, is certainly a cause of satisfaction, and gives corroborative evidence of the correctness of the conclusions arrived at.

It is not necessary to make comparisons between these results and those of New England geologists. There is not sufficient evidence yet that the New England crystalline rocks can be assigned unexceptionably to the Archean. It has not escaped observation, however, that there are many general concordances. Especially is this true of the report on the New Hampshire crystalline rocks by Prof. C. H. Hitchcock. It is believed by the writer that the same strata extend, with characteristic lithology, through the Archean terranes of New England, and that they will be identified by and by with all the necessary evidence.

REPORT OF H. V. WINCHELL.

III.

REPORT OF FIELD OBSERVATIONS MADE DURING THE SEASON OF 1888, IN THE IRON REGIONS OF MINNESOTA.

By H. V. Winchell.

The object of this report is simply to place on record the facts observed and noted during the summer of 1888 regarding the geology of the region east of Tower, paying particular attention to the iron ore deposits. During the months of July, August, September and October an attempt was made to visit all the outcrops of iron ore east and south of Ely, for the purpose of making notes, collecting specimens* and learning the relation of the ore to the rocks of the region, as well as its extent and probable value. In many cases reported by explorers and so-called "experts" it was found that their accounts either exaggerated greatly the amount of iron ore to be found at any specified place, or else that there was no iron ore there at all—nothing but iron-rusted rocks or beds of heavy dark dioryte, or even no signs of iron at all.

Region traversed. The first month was spent in examining the magnetic ore belt which lies along the north edge of the gabbro and the south side of the Giant's range. A party consisting of the writer and Mr. W. D. Willard, of the State University, with Indian packers, went overland from Birch lake to the Duluth and Iron Range railroad along the Giant's range, making frequent cross-sections of the rocks and examining all the workings in the magnetite prosecuted there in past years. After returning to Birch lake the same belt of ore was followed northeastwardly into Twp. 63-10 on the Kawishiwi river.

During the remainder of the season the party led by Mr. Uly. S. Grant, assisted by Mr. A. D. Meeds was also engaged on the investigation of the iron ores. A trip southward to lake Superior was taken through an unexplored part of the country, and the various lakes along the route were examined. The parties then proceeded to Gunflint lake and worked for a month southwestwardly. Mr. Grant's party made two or three extended trips to the south for the purpose of visiting reported iron locations, reaching Brule lake and lake Alice and making notes on the geology of their shores. The other party followed the northern edge of the gabbro to connect with the observations made from Birch lake northeastward, closing by examining some of the jasper and ore beds in the vicinity of Snowbank lake.

---

*The specimens collected by H. V. Winchell are numbered in pink shellac and alcohol, and have the letter H following the numbers.

All the outcrops of magnetic ore that could be learned of were visited,—with the exception of one or two remote places difficult of access and which were in all probability in the gabbro. Also a great many exposures of hematite were examined and many new facts obtained regarding its occurrence and relations to the surrounding rocks.

The importance assigned by many of the explorers to a small bed of jasper, or jasperoid rock in the crystalline or earthy schists, is often amusing. On the strength of such a discovery they will recommend the purchase of extensive tracts of land and the operation of a diamond drill on the spot or in the vicinity; being certain that the presence of the jasper—not always even *in situ*—is a sure indication of the proximity of a valuable body of ore. They do not seem to realize that jasper is not iron ore and that a mountain of jasper is no sign, in itself, of iron ore any more than of any other mineral.

Another erroneous idea which has gained prevalence is that a bed of ore is sure to improve the farther it is followed toward the center of the earth. The contrary is often true, and it is evident that while the grade of the ore *may* improve and the quantity of it *may* increase with the depth of a shaft, yet there is no reason to expect such a thing. Therefore it is a poor investment to buy land—or rock—which contains a small per cent of iron on top, and base hopes of a paying investment on the expectation of finding it to be high grade ore 50 or 100 feet from the surface.

It is surprising what credit is given by capitalists to any man, who, with no knowledge whatever of mineralogy or geology, and therefore no judge of the probability of finding ore in a certain locality, has, however, the assurance to tell them that there is iron in such and such a place if they will only put in a shaft and "open up the mine." On the strength of such recommendations as these thousands of acres of land have been bought at a high price, which are utterly destitute of iron ore and are, perhaps, nothing but cedar swamps or hills of bare rock; and in many places there are abandoned pits and machinery where not only shafts but fortunes have been sunk in hasty and profitless prospecting and blasting. The machinery and supplies have been "packed" thither at great expense, and men employed at high wages to dig for iron when a person who is at all acquainted with the geology of the region would have told in a short time that there was no use whatever in spending a cent. In two or three places shafts were seen sunk in greenstone where there was not the slightest indication of iron nor even a bit of jasper to mislead the anxious searcher for wealth; all because it was "on the iron range."

Such hasty, ill-advised proceedings always serve to bring a region, no matter how valuable in reality, into disrepute, and to weaken the confidence of capitalists all over the country who attribute these losses and failures to the wrong cause and are, therefore, deterred from investing their own capital in the really valuable and profitable localities.

But however much money may have been hopelessly squandered in the search for iron in barren regions, yet a great deal has been employed in the development of new and rich iron deposits during the past year. The D. & I. R. R. has been extended 25 miles to Ely, south of Long lake, from which place were shipped 1,200 tons of ore daily for about two months of last season. This ore all came from the Chandler mine, which has put in a fine plant of machinery and hoisting apparatus and will be ready for much larger shipments next year. The Pioneer and Zenith mines will also be in a condition to produce a large amount of high grade ore in 1889. These mines are located east of the Chandler at Ely. At several other places in the same vicinity large crews of men have been at work uncovering and opening up promising deposits of iron ore.

There has also been some attention paid to the Animike magnetite, and in several places around Birch lake shafts and drillings have been made. None of these, however, seem to have met with success, as the ore is not found in paying quantity.

More extensive ore-beds have been found west of Gunflint lake in Twp. 65–4 than elsewhere in this formation. Work will be commenced in this region as soon as railroad facilities can be obtained. In the following notes each of these outcrops and workings is described in detail.

Principal varieties of iron ore. It is well known by those familiar with the geology of northeastern Minnesota that there are three principal kinds of iron ore. These are found in connection with three different formations. The first kind is red hematite which is found interbedded with jasper in folded and crumpled beds that occur in what has been called the Keewatin formation. This is the ore which has been mined so extensively and is in such demand by the manufacturers of steel using the Bessemer process. Many analyses have been published heretofore. The second kind is a fine-grained glistening magnetite which is generally found in nearly horizontal beds of quartzyte supposed to be a part of the Huronian formation. This is the ore which was first worked before the Vermilion lake ore had been thoroughly tested or investigated. It has not been found in quantities sufficient to pay for mining until quite recently when large beds of it, west of Gunflint lake, have been penetrated by diamond drills. This is a high grade ore and contains no titanium. An analysis of a specimen from N. E. ¼ sec. 23, 60–13 gave the following, according to Mr. C. F. Sidener:

	Per cent.
Silica, SiO_2	11.89
Alumina, Al_2O_3	.34
Magnetic oxide of iron, Fe_3O_4	87.00
Lime, CaO	.20
Magnesia, MgO	.80
Titanium, Ti	None
Phosphorus, P	.056
Sulphur, S	Traces
	100.246
Metallic iron, Fe	63.07

The third variety of iron ore is also magnetite. It is coarse and has a duller lustre than the Animike ore and is not so strongly magnetic. It is found in many places in the gabbro, which sometimes contains so much of it that it seems to be pure magnetite. This ore almost always contains a large amount of titanic acid which ruins it for merchantable ore, with only present methods of reduction. Immense deposits of this titaniferous ore are found, and most of them have been purchased from the U. S. government in the hope of being able to conduct remunerative mining operations. When a method for reducing titaniferous ores cheaply is discovered such iron ore will be valuable; but until then it is worthless.

An analysis of a sample of this ore from sec. 36, 63–10 as reported by Mr. C. F. Sidener is:

	Per cent.
Silica, SiO_2	11.37
Alumina, Al_2O_3	1.32
Magnetic oxide of iron, Fe_3O_4	53.33
Protoxide of iron, FeO	14.42
Oxide of titanium, TiO_2	16.03
Lime, CaO	.10
Magnesia, MgO	2.73
Phosphorus, P	.01
Sulphur, S	Traces
	99.31
Metallic iron, Fe	49.40

These are the principal kinds of ore. But there are various modifications and combinations of them which would not come strictly under any one of the three heads. There are, for instance, magnetite beds in the Keewatin; sometimes mixed with hematite; sometimes all magnetite. On the other hand there is hematite and even limonite in the Animike; and there are extensive fragments of the Animike formation inclosed in the gabbro which thus appears, on a hasty examination, to contain non-titaniferous, fine-grained magnetite. The gabbro is thus found to be the only rock which always contains the same kind of iron ore—(titaniferous ?) magnetite.

GIANT'S RANGE.

The first work of the season was done, as above stated, on the syenite range south and southwest of Birch lake. The trail which leads from the lake to the Duluth and Iron Range R. R. starts from the sandy bay in sec. 32, 61–12. It runs nearly south for two or three miles after becoming established. It is a poor trail but grows better as the railroad is approached. South from Birch lake the country rises rapidly, and the aneroid indicated a hight of 225 feet at a point a mile and a half from the lake. Ridges composed of drift containing syenite boulders are crossed until in the S. W. ¼ sec. 8, 60–12 a ridge of massive syenite rises quite suddenly over 200 feet more. This is the Giants' range, 480 feet by aneroid above Birch lake. Before reaching the ridge some huge boulders of syenite and dioryte are seen. This ridge is here composed of coarse reddish syenite containing much blue, chalcedonic quartz in grains one-quarter of an inch in diameter. The pink orthoclase is frequently porphyritic. The hornblende is somewhat decayed in all the specimens observed, probably because they came from near the weathered surface. Samples of this rock are 357.

The drift on the north side of the ridge is reddish and contains many boulders. On the south side of the syenite ridge the land is from 100 to 150 feet lower than the summit of the ridge. Some immense boulders are seen.

At ¼ mile south of the S. E. corner sec. 7, 60-12 there are seen numerous angular fragments of olivinitic magnetite projecting through the moss. These pieces contain thin strata of good iron ore; they seem to lie just on top of the solid rock and to have been moved from their original place by the action of frost. Samples are numbered 358.

The trail leads through a swamp for the next half mile. Just north of the small creek which crosses the line between secs. 17 and 18, 60-12 there is an exposure of solid rock. It lies in strata which dip S. S.E. 10°-12°. The rock is olivinitic and contains considerable magnetite both as a constituent of the rock itself and in veins which coincide nearly with the direction of the bedding. This rock looks much like a quartzyte but contains a large proportion of olivine. Samples from here—S. W. ¼, S. W. ¼ sec. 17, 60-12—are 359. The rock is fine-grained and greenish; it is overlain by a very light covering of drift.

Rock similar to the last is exposed in places as far south as the E. quarter post sec. 19, 60-12. The needle dips about N. 50° over this entire distance.

In the N. E. corner of sec. 19, 60-12 is a shaft about ten feet deep. Indian John Beargrease says it was dug about 14 years ago by Peter Mitchell. After penetrating about five feet of drift the bed rock is encountered. It is the same greenish, olivinitic quartzyte containing magnetite. The needle dips N. 57°. Specimens from here are 360. Some of this rock is slaty; 361.

Another shaft has been made in N. W. ¼ of N. E. ¼ sec. 19, 60-12. The rock here is quite similar to the last; some of it is very thin-bedded. A sample from this shaft showing fine stratification is 362. . There is very little good ore visible here, though the needle dips 90°.

A smoothed, black exposure of ferruginous quartzyte several acres in extent, appears on the surface of the ground in the N. W. ¼ of N. E. ¼ sec. 19, 60-12. The rock and magnetite both weather shiny black, and the metallic lustre gives one the idea that he is standing on a hill of pure iron. Sample of good ore from here is 363.

In the N. W. ¼ sec. 19, 60–12 there is a ridge composed of syenite boulders three to ten feet in diameter. This ridge is 50 feet high and extends for half a mile at least running nearly east and west. It is wonderful to see these immense rounded masses of syenite (one boulder of quartzyte was seen among them) piled up on top of each other with crevices ten or fifteen feet deep between them. No rock is seen in the woods on the south side of this ridge, with the exception of a few boulders. This moraine seems to lie just south of the magnetic quartzyte.

Iron lake. This small lake is one of the few bodies of water that lie south of the summit of the Giant's range and yet nearly as elevated as the range. It is situated in secs. 13, 14, 23 and 24, 60–13. Its shore is surrounded by boulders, mostly syenite, from the ridge north of the lake. There are also, however, many angular pieces of magnetitic quartzyte. This rock contains less olivine here than a few miles further east. A few boulders of a quartz conglomerate with a green matrix were seen on the east side of the lake in the N. W. ¼ sec. 24, 60–13, No. 364.

A short distance east of the lake, in the N. W. ¼ sec. 24, 60–13 the bed rock was exposed in the hillside by a windfall. It is the usual black, magnetitic rock lying in nearly horizontal strata. Some of the rock here is reddish and jaspery; there is also a conglomeritic aspect in places. Sometimes the rock is slaty in thin, black, parallel strata that are quite straight for a rod or more. Again the iron seems to be in veins which do not conform strictly to the general planes of stratification. The following cut is from the perpendicular face of a ledge in N. W. ¼ sec. 24, 60–13.

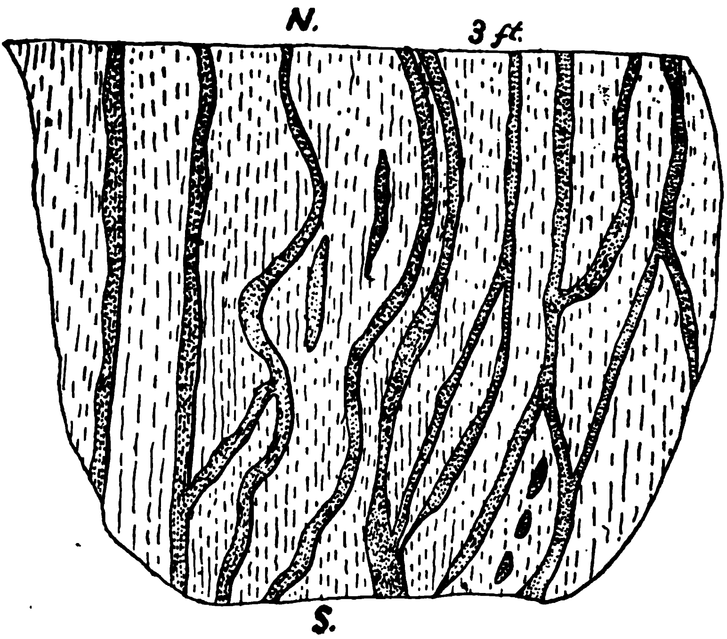


Fig. 1.—*Veins of magnetite in greenish Animike rock.*

A short distance N. W. or N. of last the ledge is exposed in a perpendicular wall 8 feet high and a couple of rods long. It is in thick black beds that have a high specific gravity and are crystalline with a dark mineral that may be hornblende, No. 365.

Near the north end of Iron lake, in S. W. ¼ sec. 13, 60-13, the magnetitic quartzyte undergoes a queer metamorphosis. It still lies in nearly horizontal beds; but it gradually becomes less highly charged with magnetite, acquires feldspathic and quartzose materials and finally is changed to a regular, reddish crystalline rock which is the syenite of the Giant's range. The lowest beds are the most perfectly crystalline. Before the transition becomes complete the Animike rock appears to be feldspathic in spots as if there were boulders of syenite in it, but lower down the beds become wholly syenitic. The quartz grains that are first seen in the greenish Animike rock have the same bluish translucent appearance as those in the syenite which lies just north. This change is illustrated by specimens numbered 366.

The quartz grains are seen before the feldspar. There are also portions of the Animike which are conglomeritic and are the same as the peculiar conglomerate, 364. A sample which contains part of a felsitic boulder is 367. The dip needle is but slightly affected here.

North of Iron lake the land does not rise suddenly; but there is a gradual upward slope for about half a mile when the summit of the range is reached and there is an abrupt descent of 200 feet or more. Syenite containing a little biotite is seen in the bluff on the north side of the range. One sample from the N. E. ¼ sec. 14, 60–13 is 368.

There are no exposures of solid rock on the N. W. side of Iron lake. On the S. W. side in the N. E. ¼ sec. 23, 60–13 there is a ledge of black magnetic rock, 369. It presents the usual characteristic aspects of this formation; lying in nearly horizontal strata and containing more or less magnetite which gives a dark color to the rock.

Iron lake is nearly as elevated as the summit of the Giant's range. The black rock on the north side of the lake is close above the syenite; and the change which was observed to have taken place must be mainly in the nature of a fragmental transition rather than a metamorphic one, i. e., the gradual increase within the Animike of the feldspathic and quartzose materials must be due to the fact that there was more or less debris derived from the crystalline ridge on the north which was covered up by the Animike deposits and by subsequent metamorphism incorporated closely into them. That this metamorphosing process was in the nature of a slow rearrangment and reuniting of the mineral constituents rather than of a violent and more sudden disturbance seems to be indicated by the comparatively undisturbed position of the strata.

Mr. Willard went south from the lake through the S. W. ¼ sec. 23, and the W. ½ sec. 26, 60–13. He reports fragments and low outcrops of the dark iron ore rock all the way to the swamp in the N. W. ¼ sec. 35, 60–13. Sample from that locality is 370. It is tough, black, heavy rock and contains probably 45 per cent (?) of iron.

The percentage of iron in the rock appears to grow less going westward from Dunka river; toward the northern edge and westward there is also less olivine and more quartz. Fragments of red jasper are seen all along the trail. These may have been transported from north of the Giant's range, although red jasper and quartzyte have been seen in the Animike formation in this region. Pieces of porphyritic rock that look as if they belong to the same formation near its contact with the syenite are also seen along the trail.

Some pure quartzyte containing, however, a small amount of magnetite, is found in angular fragments. A sample of reddish-gray quartzyte from N. W. ¼ sec. 32, 60–13 is 371.

The bed rock is seen to be just beneath the moss and light drift covering for two or three miles in sections 28, 32 and 31, 60–13. Ridges composed of granite and syenite boulders are seen at intervals, and evidently form part of a morainic system. The drift deposits become thicker toward the west.

Just south of the trail in S. W. ¼ of N. W. ¼ sec. 32, 60–13 is a large exposure of the semi-crystalline fragmental rock which intervenes between the regular Animike and the syenite, and grades into the latter. This rock is exposed here to a depth of 12 or 15 feet. At the top it contains considerable green, uncrystallized material, and the feldspar crystals are not so well formed as farther down where there is less of the green matter. There is an indistinct gneissic structure which seems to lie nearly horizontal; there is also a coarse schistosity which runs N. E. and S. W. At the top is a conglomeritic layer which contains pebbles of quartz and some of greenish rock, some of them two inches long, but mostly less than an inch in length, No. 372.

The rock at the bottom of this exposure is almost wholly crystalline with the usual constituents of syenite. The hornblende crystals are the last to be developed; large crystals of feldspar appear in the green matrix before it begins to show any other signs of crystallization. These feldspar crystals are orthoclase and are sometimes blood-red.

Peter Mitchell uncovered the iron ore beds in several places in the S. W. ¼ sec. 32, 60–13. Some of the rock thus exposed is quite slàty, 373. The shaft in the S. E. ¼ S. W. ¼ sec. 32, 60–13 is about 8 feet deep. It penetrates solid, black rock containing magnetite in grains and poorly defined layers or bands all through it. It is poor ore. On the surface a short distance northwest of the shaft the rock is more unevenly bedded and consists of thin veins of black ore in a gray rock. No. 374. The needle dips at all angles in a very small radius here. Glaciation is about N. N. E. Some of the rock is fine and jaspery with a reddish tinge, No. 374 A.

This is in a low ridge trending N. E. and S. W. or thereabouts. Sometimes similar ridges are seen made of boulders, and sometimes of syenite. In the S. W. ¼ sec. 31, 60–13 is a small ridge composed of iron ore rock. It has been broken off and the land east and north is lower. The east face of the ledge is smooth and vertical and can be followed for half a mile on the north side of the trail. The grayish, quartzose rock lies in nearly horizontal beds, all of which contain magnetite. This rock always weathers shiny, smooth and black and has the appearance of solid iron. There is very little pure ore in these beds. A sample from the S. W. ¼ sec. 31, 60–13 showing the weathered surface is 375.

There is a large exposure of the Animike rock and a shaft dug down about ten feet by the side of the vertical exposed wall of rock in the N. E. ¼ sec. 11, 59–14. There is here seen a thickness of 15 feet of the usual dark-colored rock. It is, however, reddish in streaks and contains a little hematite with the magnetite. At the bottom of the shaft, particularly, the rock is soft and hematitic. At the surface of the ground the rock is harder and seems to be composed of reddish quartz in fine grains strongly resembling the "chalcedonic" quartz of Vermilion lake, 376. Hematitic rock from the base of the shaft is 376 A. There are thin bands of good ore contained in the rock here; but there is not enough to pay for working. This ledge is on the west side of a ridge which trends to the northwest. The strata have a little higher dip than usual toward the southeast. Some of the ore is seen to be further altered to limonite.

In the N. W. ¼ sec. 11, 59–14 is a small outcrop of Keewatin rock.* It lies in vertical beds striking N. 80° E. Sample is 377. In the S. E. ¼ of the same section and particularly in the S. E. "forty" there is a great deal of this rock. It rises in a ridge 15 feet above a cedar swamp. It is feldspathic or felsitic and stands in vertical strata having the usual strike for this formation. Samples are 378.

Prof. A. H. Chester, in the Eleventh Annual Report Geology of Minnesota, p. 156, speaks of hematite boulders in a layer of black sand, which he observed at the bottom of a shaft 15 feet deep in Animike, a short distance north of here. Perhaps they were on top of the Keewatin and were covered up by the Animike sediments.

The Animike beds appear to be considerably broken in this region. Several very large masses of strata were seen that were in horizontal position and evidently but slightly disturbed from their original position. Some of them are on the hill above the Keewatin and only about 200 feet away from exposures of it in the S. E. ¼ sec. 11, 59-14. There seems to be no reason to doubt that the black iron ore rock lies horizontally and unconformably on the upturned edges of the Keewatin. We dug a shaft by the side of a large, flat-lying mass of Animike here. It was not proven to be certainly *in situ;* but had evidently been but slightly disturbed. In this same section in various other places Animike in place is found lying above exposures of Keewatin quite near; but no actual contact was seen.

---

*This is believed to be the first observation reported of the existence of the green schists of this formation south of the Giant's range.

There is another shaft in the iron ore rock in the N. W. ¼ sec. 14, 59-14. It lies nearly horizontal and the rock has the usual gray, arenaceous, magnetitic appearance. It is glaciated on the surface but the direction could not be taken owing to the magnetic disturbance. One sample from here is 379.

The black slates and quartzytes in sec. 22, 59-14 do not seem to be so magnetitic, but contain veins or bands of blackish quartz or jasper. This jasper is granular and upon being pounded it crumbles and displays many white grains. The rest of the rock is grayish and is penetrated by fine needle-shaped crystals of hornblende (?) No. 380.

In the S. E. ¼ sec. 17, 59-14 there is an outcrop of the schist which is supposed to be Keewatin. It is in vertical beds which strike N. 75° — N. 80° E. It is dark gray and soft but siliceous and sericitic, 381. This is only about one mile south of Hinsdale and is remarkably close to the syenite ridge which rises 150 feet or more higher, a mile north of this exposure. The syenite appears only half a mile north of here. The dip of the schists is vertical or at a high angle to the south.

The rock which forms the highest part of the Giant's range at Hinsdale is syenite which frequently has a distinct vertical gneissic structure. This syenite is reddish near the surface, but is gray about 30 feet below. It contains porphyritic crystals of pink orthoclase, which become deep red in places. There are lenticular masses of dark, hornblendic rock inclosed in this syenite at all depths. Some of these inclusions are five or six feet in diameter. They are always elongated perpendicularly and consist generally mainly of hornblende, 383.

A few intrusions of fine gray granite and pink granulyte are seen to penetrate the syenite. Epidote colors the rock in the proximity of veins and faults or fractures. Quartz and feldspar veins of limited extent are not uncommon.

The rock is a handsome one for ornamental purposes, and columns or blocks of any required dimension quite devoid of flaws or cracks can be obtained. It has been quarried for the manufacture of paving stones. It is also being employed in the erection of the Round house of the D. and I. R. R. at Two Harbors. Twenty-five samples of this rock were obtained, 382. Glaciation is very fine on top of the ridge, N. 22° E. The summit of the range is 120 feet by aneroid above the station at Hinsdale.

North of Hinsdale there is a rapid descent in the level of the country. At one mile and a quarter from the station is a low outcrop of syenite. It is quite similar to that in the ridge. It outcrops again at 2 miles and still again at about 3 miles north of Hinsdale station. At the last place it is red and dark and the hornblende is decayed. Small geodes of quartz and calcite crystals are seen in it here. One sample is No. 385. The level here is 180 feet below the top of the ridge at Hinsdale. There is considerable drift mixed with numerous boulders of syenite at this place and all along back to the ridge.

The last syenite seen on the railroad north from Hinsdale is about five miles from the summit of the Giant's range. It is reddish and lies in low outcrops. For the next mile or two the country is low, flat and swampy. Then come knolls and ridges of Keewatin dipping about N. 75°. The dip is lower than on the south side of the ridge or at Tower. Veins of calcite are noticed in the rock.

It is noticeable that no Animike either in place or as boulders is seen north of the Giant's range. The ridge of syenite is about six miles wide from north to south where the railroad crosses it.

John Mallmann in charge of a crew of 25 men was at work in sec. 29, 59–14 sinking shafts through the drift and down to the underlying rock in search of iron ore. He finds the rock to contain both hematite and magnetite. Some of it is colored quite red by sesquioxide of iron. At depths below the surface varying from 15 to 40 feet the bed rock is encountered. It consists of thin strata of grayish rock which might be termed ferruginous quartzyte, but it is not pure quartz and iron ore. Some of it has an indistinct conglomeritic appearance, the pebbles being fine, grayish or greenish or sometimes hematitic. The beds are not as a rule more than 6 or 8 inches thick and have a low dip to the south or southeast. The syenite is said to lie about ¼ mile north of here. Much of the hematite found in these shafts shows a further alteration toward limonite.*

Red, hematitic rock having the usual dip and appearance of hematitic Animike strata is seen in a shallow railroad cut about ¼ mile south of Mallmann's camp.

Mr. Willard visited Partridge river and examined some exposures of rock in the neighborhood. Gabbro was seen in a railroad cut ¾ mile north of Beaver creek, sec. 5, 58–14. It was exposed for 150 feet along the track. It was somewhat decomposed and weathered into rounded, boulder-like forms, 386. One-quarter of a mile farther south is another cut through gabbro. The same rock is seen on the south side of Beaver creek about a hundred paces from the railroad track, and in fact forms all of the knolls and is seen in all of the cuts for some distance south of Beaver creek.

On the south side of Partridge river, about in the N. E. ¼, S. W. ¼ sec. 9, 58–14 just above a small creek is a low outcrop of black or dark-gray, siliceous, thick-bedded slate which seems to dip about 20° N., 80° E. A system of vertical joints pervades this rock, the general direction of which is about east and west. About 200 feet down stream from here the river runs over the edges of these beds of slate. Following the rock for some distance down stream an old shaft is seen but no interesting features are exposed by it. It is in a ridge whose course is nearly north and south. Exposures of this same rock were noticed in several places in this vicinity; the ledges rising about 8 feet above the general level. The gabbro overflow surrounds and nearly covers this rock. The strike of the slates where the strata have been broken or lie in ridges for any distance, is N. 10° W. This rock is not exposed over a region exceeding 350 feet in diameter. It seems to be a little of the Animike formation which was not

---

* An analysis of this limonite, made by Mr. C. F. Sidener, gave the following:

Silica, Si O_2	3.52 per cent.
Sesquioxide of iron, $Fe_2 O_3$	87.10 per cent.
Manganese	traces.
Lime and Magnesia	traces.
Phosphorus, P	.023 per cent.
Sulphur, S	traces.
Water, H_2O	9.70 per cent.
	100.343
Metallic iron, Fe	60.97 per cent.

covered by the gabbro overflow. It is not iron-bearing here to any appreciable extent as are the strata generally farther north. It occurs in thick, homogeneous beds in which the sedimentation is quite evident. It is silico-argillaceous and seems to be carbonaceous. Samples are numbered 387. The rock lies in lower ground than the surrounding gabbro knolls, between which and the slate a swamp intervenes.

In the N. E. ¼ of the S. E. ¼ sec. 11, 59–14 is a shaft five feet deep. No rock *in situ* appears to have been encountered in it; but many fragments of reddish-gray, quartzose rock are seen in the sides of the shaft and on the surface round about. This land is 140 feet lower than that ¼ mile north of here. Samples of reddish hematitic ore from here are 388.

About 250 paces west of the east quarter post of sec. 11, 59–14 is a shaft dug to a depth of ten feet by the face of a north and south ledge of rock. The strata here dip about 15° slightly to the south of east. Good iron ore is seen in veins or bands 2 or 3 inches thick in the face of this ledge. This wall of rock is exposed for several rods north and south of this shaft. It is noticeable that the prevalent direction of the joints in this formation is north and south.

In a part of sec. 11, 59–14 which was visited on our return to Birch lake, near the center of the section, Keewatin rock is found standing as usual in vertical strata. It is quite feldspathic. Above it, separated by a few feet only of unexposed rock covered by drift, are masses of Animike strata 15 feet long and 8 feet thick which seem to have been but slightly disturbed from their original position. A sample of the Keewatin rock is 389. There are quartz veins in it which contain talc-like scales. 389 A. Some of this vertical schist is graywackenitic and some granulitic. Some resembles the rock found at Partridge river supposed to belong to the Animike, 390.

Outcrops of felsitic, siliceous schist in vertical strata with a strike N. 80° E. are seen in N. E. ¼ sec. 15, 59–14 near the north section line; 391.

Southeast from the last about 200 paces and 40 feet higher is found a large solid outcrop of iron ore rock. It rises five or six feet and is seen for four or five rods. It is horizontally stratified or has a dip of less than 10° to the east. This is considered as certainly lying unconformably on the vertical Keewatin. No. 392 is from here.

There is another ledge of iron ore rock (Animike) in N. W. ¼

N. W. ¼ sec. 14, 59–14 near the center of the quarter section. Some good ore is found here, 393. From the way in which the Keewatin schists are found to underlie all this Animike an observer receives the impression that an iron mine or iron lands in this formation *here* are not of much value, for it is doubtful whether a shaft 40 feet deep could be made in the iron ore rock anywhere in this township without passing through it and reaching the Keewatin.

Fragments of the Keewatin rock are seen all along the trail in Twp. 60–13, indicating that it outcrops somewhere and perhaps at several localities between the trail and the syenite ridge. The number of rough pieces of Animike rock that are everywhere seen along this trail show what was the entire surface of the land south of the Giant's range and indicate that the region immediately south of the ridge was to a great extent protected from the force of glacial erosion.

A sample of quartzyte which was seen in angular fragments in 60–13 was obtained as showing fine stratification. It contains a little magnetite in bands which fade out completely in this specimen. No. 394. Deposits of magnetic sand are seen on the shore of Birch lake where the trail starts out, S. W. ¼, S. E. ¼ sec. 32, 61–12. No. 395.

BIRCH LAKE REGION.

Tonga or Dunka (sand) river. This name is bestowed by the Indians on account of the extensive banks of reddish sand and gravel which form the shores of the lake near the mouth of the stream and also compose the bed of the river for a short distance above the lake. Mingled with this red sand is more or less black magnetic sand sometimes in such quantity as to make the beach black. An instance of this is in the S. W. ¼ sec. 33, 61-12.

For a mile up this river there is a large amount of drift containing many boulders. The land rises in east and west ridges 100 feet or more above the river. Near the south side of sec. 4, 60–12 the ridges seem to be composed almost wholly of large granite and syenite boulders. It can not be ascertained certainly whether they are underlain by rock of the same nature *in situ* or not.

South of this ridge is another in S. ½, N. W. ¼ sec. 10, 60–12* which has, exposed on the surface, many angular fragments of semi-stratified rock consisting mainly of magnetite and olivine with some quartz. This rock appears to be *in situ* at two or three places on the north side of this ridge and to dip S. 70°-80°. Syenite is found in ridges south of here, and some distance south of them is found the gabbro. The Animike, therefore, has here a range of syenite between it and the gabbro. Samples of the iron ore rock from 400 paces east of the west quarter post sec. 10, 60-12 are 356. The needle dips N. 60° to 70° here.

---

* This ridge is referred to by N. H. Winchell, in his fifteenth annual report, p. 341.

Other localities around Birch lake. Pursuing a trail which leads south from the lake, starting in the N. E. ¼ sec. 26, 61-12 toward some claim cabins in sec. 35, 61-12 some interesting rocks were seen. A short distance from the lake is a knoll of fine-grained crystalline rock which is generally considerably decomposed and yellowish in color. It has the composition of gabbro and is apparently the rock that first cooled on the outer edge of the gabbro overflow. It contains both biotite and hornblende sparingly, also olivine and magnetite, but is principally made up of labradorite. There are spots in it of light-colored feldspathic rock which appear to be boulders whose outline is not distinguishable from the rock mass. A sample of the fine gabbro or muscovado-like rock is 396. A sample from one of the boulder forms is 396 A. These are from the N. E. ¼ sec. 26, 61-12. This gabbro appears in small, detached knobs lying on the Animike iron ore beds. These beds are somewhat disturbed and broken and vary in dip to the southeast from 12° to 30°. Near these knolls of gabbro the iron ore rock is semi crystalline, containing porphyritic crystals of hornblende sometimes two and a half inches long. Specimens from here are 397, 397 A, and 397 B. There are large outcrops of this Animike rock here. Sometimes the stratification is not very evident, but generally it is distinct and well-marked, 398.

The beds here have the same vertical joints running north and south; and present east and west vertical faces from four to fifteen feet high such as are seen south of the Giant's range. Loose, angular fragments of Keewatin schist are seen here and probably lie near the surface in the vicinity under the Animike. Some of the Animike is almost all quartz which forms a coarse granular sandstone on decomposing. A specimen from the E. ½, N. W. ¼, sec. 35, 61-12 is 399. Glaciation here is about N. 15° E.

In the S. E. ¼, N. E. ¼ sec. 35, 61-12 are several ridges of magnetitic quartzyte having vertical faces 15 feet high on the west side. A few feet west of one of these walls of rock there is a knoll of syenite. The latter is porphyritic with pink and white feldspar and contains both biotite and hornblende, together with a considerable proportion of quartz. It rises in the knoll as high as the top of the quartzyte ridge but slopes down and runs under it. The syenite is 400. The quartzyte is in beds which are nearly horizontal and seem to have about the same texture and composition where it lies on top of the syenite as they have ten feet higher up, 401. A claim cabin is located on the syenite ridge only a few rods from the quartzyte ledge. The syenite is cut by a few veins of fine, pink granulyte. The situation is shown in Fig. 2.

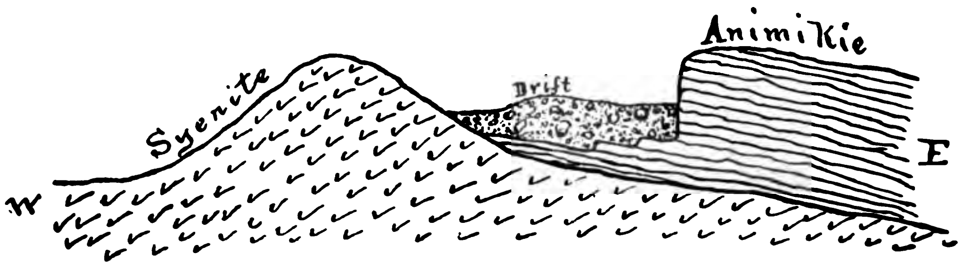


Fig. 2. *Relation of syenite and Animike ridges.* The little valley between the two ridges is about 12 feet deep and 35 feet across. The west face of the quartzyte is perpendicular. The land is covered with small pines.

A trench was made with some labor from the quartzyte to the syenite thus exposing the manner of contact. The Animike was found to lie on the syenite in a thin, hard, hornblendic stratum about six feet from the main mass of exposed syenite. It was buried under about five feet of till with hardpan at the bottom. Samples of the layer of Animike rock found lying on the syenite are 406.

In the first shaft that was dug down at the foot of the Animike bluff a large mass of greenish Keewatin rock was encountered that prevented further excavation at that place. This rock, which was supposed to be a drifted fragment, was coated with a crust of calcite crystals all over the top. In several places the syenite was seen to have a thin layer of the hardened Animike rock adhering to it which had not been removed by glacial scraping. From the appearance of such rock it seemed as though the abrading action of the ice was not so violent as is generally supposed.

In the N. E. ¼ of S. W. ¼ sec. 35, 61–12 the magnetitic quartzyte is exposed in many places. It seems to have been affected by some metamorphosing agent which has produced large crystals and masses of crystals of hornblende in it. Some of these crystals are three inches long. They frequently are rounded or lenticular as a whole mass and suggest included boulder forms, 402.

West and northwest from the last locality the ground rises and syenite is found outcropping in quite extensive ridges. This is near the west quarter post of the section.

Toward the S. W. ¼ sec. 35, 61–12 the land rises until it is 200 feet above Birch lake. On this high land many large, smooth-topped exposures are produced by recent extensive wind-falls. The strata seem to have been disturbed and slightly elevated by some force from beneath. The usual dip—less than 30° to the southeast—is, however, still maintained. This rock is coarse and more quartzose and has quartz veins penetrating it. Glaciation is finely exhibited in many places and seems to vary, as near as could be estimated, by comparison with the section lines, from N. 12° E. to N. 30° E. Syenite is reported to outcrop about one-half mile west of the S. W. corner sec. 35, 61–12. Some of the beds of this Animike rock are but slightly iron-bearing and are almost wholly composed of olivine, 404.

In the N. ½ of the S. E. ¼ sec. 24, 61–12 there are several exposures of Animike rock in shafts which have been dug in the search for iron ore, as well as on the surface. The rock is dark, heavy and magnetitic and exhibits fewer sedimentation bands than usual. But it has the general dip of this formation and is rich in olivine. There have been six or eight shafts sunk at this place; some of them are nine or ten feet deep and furnish good sections of the rock strata. Some thin strata of rich magnetite are seen in the rock; but they are always separated from each other by beds of poor ore or of quartzyte, 405. Much of this rock is hornblendic; the crystals appear right in the middle of olivinitic and finely granular strata containing more or less magnetite. These crystals of hornblende are in the strata ten feet below the surface beds, and are sometimes two inches long or more, 405 A. In places the rock has been moved on itself and has thus formed fine slickensided surfaces, 405 B.

There is a heavy covering of drift sand and boulders here. Granite in place and gabbro lying on it were seen a short distance farther east in the S. E. ¼, N. W. ¼ sec. 24, 61–12. The Animike beds seen in the vicinity were in knolls that rise above the granite and gabbro and are estimated to be 150 feet above Birch lake. A thickness of about 25 feet of the iron-bearing strata was seen in the various shafts.

This same rock outcrops on the west side of the little bay in S. E. ¼, S. W. ¼ sec. 24, 61–12, a short distance back from the shore. At this place it is much decayed and jointed.*

Vicinity of Kawishiwi river. Going south on the range line between townships 62–10 and 62–11 on the south side of the river in S. E. ¼ sec. 13, 62–11, search was made for the iron ore reported by Mr. Lorenzo Cleaves. Nothing was found for half a mile except syenite in a ridge about 75 feet, by aneroid, above the river. Then there is a swamp and a creek, and gabbro hills are reached in S. W. ¼ sec. 19, 62–10. These hills are but a little over 100 feet above the Kawishiwi. The gabbro is seen in bare knobs and vertical bluffs 20 to 40 feet high. Some masses of gabbro 30 feet in diameter have been pushed up on top of the smoothed knolls of solid rock and left there by the ice.

In the S. E. ¼ sec. 30, 62–10 are several shafts, some more than 20 feet deep, in magnetite ore. The magnetic attraction is very strong here and the needle dips 90°. There being more than a mile and a half of gabbro north of this place and this iron ore itself being in hills of gabbro 100 feet high it would naturally be supposed that this ore is gabbroitic magnetite and therefore titaniferous.

But the ore is olivinitic and generally quite fine-grained, and the rock which contains it is not a massive crystalline rock like gabbro, but stands in beds which are nearly vertical, though the dip is not constant. These strata are olivinitic and besides being finely granular, possess a banded structure and are evidently *transported beds of Animike strata contained in the great gabbro overflow.* Whether they are between overflows of different dates or were surrounded and taken to their present position at the time of a single eruption was not evident, but the latter is more probable. The gabbro itself being also largely composed of magnetite here renders it more difficult to distinguish between the two kinds of rock. Samples from the S. E. ¼ sec. 30, 62–10, showing banded structure supposed to be due to sedimentation are 407. Specimens of the coarse gabbro magnetite are 410. The Animike is quite hornblendic here as at the locality north of Birch lake, sec. 24, 61–12. The gabbro which forms massive knolls all around this place is not so much decayed as the iron quartzyte, nor does it display any banding nor any other signs of bedding as do the enclosed strata of Animike.* The general strike of the latter is east and west.

---

* N. H. Winchell, Fifteenth annual report, p. 335.

A trip was made from the Kawishiwi river in N. W. ¼ sec. 25, 63–10 southeastward into sec. 36. Gabbro ridges and knolls from 70 to 100 feet above the river are crossed. Many large fragments of greenish schist from farther north lie on the surface, also boulders of syenite and amphibolyte or dioryte. This gabbro is rather coarse and is magnetitic in spots and streaks; 412. There are belts of coarse hornblende and labradorite found in it. 412 A. Included in the gabbro are irregular masses of all sizes of fine, grayish rock that seems to be composed of rounded grains and resembles Animike. There is no evidence left of former stratification, and in places where it has been highly altered this rock has the composition of a fine gabbro. But the transition from it to the gabbro is always abrupt and the outlines of the included masses of it are plainly seen. 413. This rock is slightly ferruginous if at all; but the gabbro contains much shining, coarsely crystalline magnetite. 414.

In the S. E. ¼, S. E. ¼ sec. 25, 63–10 the gabbro contains some large masses of very coarse hornblende. There are places in the gabbro four to six feet in diameter which contain or are wholly made up of black hornblende crystals six inches long. There is a little mica in connection with it, also some coarse labradorite. 415.

Vicinity of Long Lake. The hills in the N. W. ¼ sec. 20, 63–12 are composed of diabasic rock. They rise about 100 feet above

---

*An analysis of the magnetite supposed to belong to the enclosed beds of Animike and therefore to be non-titaniferous, was made by Mr. C. F. Sideuer. No titanium being found in it the effect of the gabbro does not seem to have been intense enough to invest the magnetite with harmful ingredients.

Silica, SiO_2	11.39 per cent
Alumina, Al_2O_3	Traces.
Magnetic oxide of iron, Fe_3O_4.	85.55 per cent
Titanium, TiO_2	None.
Lime, CaO	.22 per cent
Magnesia, MgO	3.44 " "
Phosphorus, P	.02 " "
Sulphur, S	Traces.
	100.62 " "
Metallic iron, Fe	61.95 " "

the lake, and in them are seen the same coarse boulder forms* as have been noticed in this rock farther east, also at the railroad cut near the Chandler mine, on the south shore of the lake in sec. 28, and in the N. E. ¼ sec. 5, 62-12. On the north side of the first ridge north of the lake the rock is not so diabasic, but is the usual more or less fissile sericitic schist.

In the N. E. ¼ sec. 9, 63–12 the sericitic schist changes rapidly across the strike, going north, into granite, becoming first siliceous, then felsitic or feldspathic and finally micaceous. Specimens illustrating this are Nos. 416 to 416 E. The granite still preserves in places a coarse vertical schistosity. North of this granite, which continues only for a short distance, is hornblendic biotite schist crossed by veins or intrusions of syenite and granite; 417. This dark schist is in vertical strata having the usual strike of about N. 60° E. The lake which lies in sec. 4, 63–12 is about 75 feet higher than the lake just south of it.

Going overland from the lake to the N. W. corner sec. 4, 63–12 the rock is found to be hornblende-biotite schist dipping north at an angle of 75° or more. Most of it is very dark colored and heavy, 418. Nothing was seen of the belt of magnetic iron which had been reported to exist in this section.

Going south from Ely into sec. 4, 62–12 the rock is found to be mostly covered by a thick deposit of drift until the N. W. ¼ sec. 4 is reached. Here there is seen an abrupt ridge of sericitic green schist striking N. 60° E. and having a vertical dip. This ridge rises 75 feet above the swamp on the north side of it. The rock contains considerable calcite as at Ely. 419. Going west several pits are seen dug in the low ground north of the ridge. All of them penetrate a soft reddish rock strongly impregnated with iron similar in appearance to that in the mines at Ely. It seems probable that the depression north of this ridge may have been produced by reason of the softer nature of the iron ore beds which may lie in there. And it is not at all unlikely that rich beds of soft ore underlie the swamp referred to. In the N. E. ¼ sec. 5, 62–12 a large, glaciated surface of the green rock is exposed. There is here a fine exhibition of the coarse agglomeritic structure mentioned above. A diamond drill just east of this place has gone down 60 feet in the same rock.

---

*This is referred to by Mr. A. C. Lawson in his report on Lake of the Woods as a "concretionary (?) trap structure."

LAKE SUPERIOR TRIP.

The country south and east of Bald Eagle lake (the Indian name for this lake is *Mishiwishiwi sagaegan* or Beaver-house lake) has been burnt over and is now covered by a small growth of aspens, birch, jack pine, spruce, etc. It is rocky and hilly, the hills of gabbro rising 100 feet or more above the general level. The route to lake Superior lies up the river which enters the south side of Bald Eagle lake. This stream is smooth for a short distance and has low swampy banks. A rapid where the river falls 50 feet is then encountered and above it again the smooth, currentless stream. The solid rock is all gabbro and most of the boulders are of the same material, though there are a few boulders of Keewatin greenstone and of granite. On the first portage there are seen some large pieces of white vein quartz. The gabbro for a mile or two is almost wholly composed of labradorite. In one place was seen quite an accumulation of boulders of siliceous greenish rock like that at the west end of Knife lake.

The land in the S. W. ¼ of township 62–8 is quite uniformly level. The lake in sections 29 and 32 has low shores, mostly marshy. The rock is gabbro, many boulders of which lie around. The lake and river seem to be almost on top of the gabbro ridge, the hills around them are so low.

Lake Isabelle. The shores of the west side of this lake are composed of gabbro. They are generally about ten feet high, but sometimes rise to forty feet. The gabbro is very much decayed near the surface. It is composed principally of labradorite; but contains some biotite and a little magnetite. There are occasional small pieces of granular olivinitic rock, supposed to be Animike, enclosed in the gabbro. They are hard and sometimes have a basaltic structure. A sample of gabbro from N. W. ¼, S. E. ¼ sec. 35, 62–8 is 420. There are numerous boulders of fine siliceous greenstone from farther north seen lying around the shores of the lake. The Indians call this lake by the same name as Gabbro lake, viz.: *Kazushkonabigka-gamak*, the lake-with-the-shores-of-shelving-rock. On the east side of the point last mentioned is a beach of sand and pebbles. The latter consist of siliceous greenstones, porphyrytes, granites and gabbro, 421.

The gabbro in the bay east of this point is smoothed by glaciation and considerably decayed. It contains in one place ten feet of hard, greenish rock in a dyke or bed about a foot wide, which seems at first to be trap, but is not massively crystalline and seems to contain some rounded grains, and therefore may be Animike rock hardened by the action of the gabbro.

In the S. W. ¼ of S. E. ¼ sec. 36, 62–8 there is a dyke 16 inches wide exposed for 30 feet. It is perfectly straight and is composed of tough green rock. The dyke walls are well-defined and it maintains the same width for the whole distance of its exposure. This rock hardly appears like trap; it is too granular and not sufficiently crystalline. Neither can it be said to resemble the Animike rock. The direction of this dyke is N. 64° E. 422.

In the S. E. ¼ sec. 36, 62–8 the gabbro stretches out in long, low reefs into the lake. Beds of sand which is the result of rotting gabbro occupy the hollows. There seem to be layers or beds in this gabbro that are like the rock found in the dyke, 422. The question arises whether this rock was igneous and flowed over on the gabbro or whether it is changed Animike enclosed in it. Glaciation is N. 24° E.

Some of the gabbro is fine grained and brown and contains more biotite than the gray. Perhaps this is what has been called "muscovado." One sample from the south shore of the lake just east of the range line in Twp. 62–7 (unsurveyed) is 423.

Swamp Lake river (*Maskigo-sibi*) enters lake Isabelle on the east side. This river is a series of lakes connected by a small stream. About two miles up this stream a change takes place in the gabbro. It is found to be composed of reddish feldspar and much hornblende with a little biotite, magnetite, pyrite and sometimes galena. Streaks of this reddish gabbro are first seen running through the gray and then it all becomes red, and large massive knolls are formed of it. Nos. 424, 424 A. and 424 B. illustrate this change.

The route to lake Superior lies through the series of small lakes connected by a stream which comes from the east and southeast. This stream is very rocky and full of rapids and comes from Kaminisabikokak lake which has been re-named lake Bellissima. This lake is about two and a half miles across from east to west and four miles long from N. W. to S. E. It is situated in the southeast part of Twp. 61–7, and perhaps extends into Twp. 61–6. Notwithstanding the rapids in the river a person receives the impression that the country is unusually level. No hills of any considerable hight are seen, and at times the stream is merely a narrow lake a mile or more in length with a low rapid at each end and shores not over 20 feet high. The country has all been burnt over and the only trees are small poplar, birch, willow and jack pine. A great many boulders principally of gabbro are seen on all hands. There are also boulders of trap and red Cupriferous rock for two or three miles west of Bellissima lake. The solid rock is all gabbro. West of the lake it is nearly pure labradorite, but toward the east it is associated with a larger proportion of magnetite. It decays rapidly and crumbles apart forming beaches of sand which is nothing but decomposed labradorite feldspar. The Indian name for this lake is applied with reference to the large number of boulders which line the shores and stand several feet out of water at some distance from the shore all around the lake.

There are sand and gravel beaches, beaches of small cobble stones, beaches of moderate sized boulders, and beaches where the boulders average more than six feet in diameter, while some are fifteen to twenty feet. The largest boulders are of gabbro; but many of the smaller ones are greenstone or red amygdaloidal trap. There are comparatively few exposures of solid rock around this lake, but all the rock that is seen is gray gabbro.

The stream which enters the southeast corner of the lake is canoeable for only a short distance, about half a mile above Bellissima lake. A portage of a half a mile is then made to a small lake and then another portage of one and a half miles south to lake Gaokakag, or lake Harriet. The country has a heavy covering of drift sand and gravel and but little rock is exposed. Many of the pebbles and boulders are from the Cupriferous. Occasionally there is seen an outcrop of gabbro, quite coarse and containing considerable magnetite. The surface is rolling and open, having been burnt but a few years ago.

Lake Harriet is about two miles long. It is a beautiful body of water set in hills heavily covered with white pine around the south half of the lake. High water is maintained in it by a beaver dam at the outlet. The long portage necessary to make in order to reach the lake from the north cuts off an impassable part of the river. This lake is 70 feet higher than the small lake at the north end of the portage. The country between these two lakes is good farming land, but is now nearly bare, having been burnt recently.

At the outlet of lake Harriet there is a massive exposure of reddish-gray rock, which crosses the river and forms a rapid.

GUNFLINT LAKE.

A small stream from the north enters the east end of the lake just north of the boundary river. A few rods west of the mouth of this creek gabbro is seen lying in Animike slates. About one-eighth of a mile up the creek rock in place is noticed. This is a ridge of vertically bedded rock supposed to be Keewatin. Strike is N. 80° E. Dip is not constant. Some of it is fine-grained and flinty and resembles the Knife lake rock. 433. Farther up on the east side of the creek the same rock is coarser and not so siliceous, but contains chlorite or sericite. No. 434.

It was because of reports of red jasper being found here that a visit was made to this creek. This jasper was found to be in beds of Animike lying horizontally on the opposite side of the bed of the creek from the Keewatin. The bed of this stream lies in the line of contact between these two formations. The Animike is flinty and becomes more reddish farther up the creek, 435.

About one-quarter of a mile up the stream the creek spreads out into a marshy lake. A north and south Canadian survey line between 297 T and 298 T crosses the creek at the head of the rapid water. At this place, on the east side of the stream, are thick beds of horizontal Animike. It has here the nature of a somewhat decomposed, fine, dark conglomerate. The pebbles in it are iron rusted; they are sometimes an inch long, but generally less than half an inch. They are flattened horizontally, 436. On a knoll above this conglomerate, a short distance east of it is found another outcrop of schistose Keewatin. It is greenish and somewhat sericitic, 437.

In the bed of this same creek there is found the contact between Keewatin and Animike. The two rocks are very similar in appearance and texture at the point of contact, and it is only by following up what is plainly Keewatin on one side and what is known to be Animike on the other until they come together that the junction could be determined. Even then the actual line of contact could not be seen, being in the bed of the creek of running water; but a person can stand with one foot on rock that is plainly horizontally stratified and is magnetitic, and the other foot on a slightly different rock that is lighter colored, contains no magnetite and has vertical bands of sedimentation. The space between is occupied by rock that may belong to one formation or to the other and is somewhat broken up. The best place to observe this contact is at the water's edge on the east side of the brook. The Keewatin strikes N. 80° E. and has a high dip to the north or is vertical; a little farther down the creek, however, it dips S. 75°. A ridge of the Keewatin on the east side of the stream rises above the Animike which lies unconformably in almost flat beds upon and against it. The Animike is 438. Specimens of the Keewatin are 439.

Going south from Gunflint lake to Loon lake a ridge of gabbro 300 feet high is crossed. Loon lake is 195 feet above Gunflint by aneroid. Mayhew lake is 110 feet above Loon lake. It is surrounded on the west side by low gabbro hills. This gabbro contains considerable magnetite. Several claim cabins are located on this gabbro ore. The gabbro in Tucker lake just west of Mayhew lake is also magnetitic. It is quite coarse and decayed and presents a gneissic or foliated appearance. A sample from N. E. ¼, N. W. ¼ sec. 2, 64–3 is 440. In the S. W. ¼,N. W. ¼ same section there is some fine dioritic looking gabbro which also contains magnetite. 441. This lake being 305 feet above Gunflint it is not likely that there is any Animike exposed on its shores; and indeed none was seen.

In the S. E. ¼,N. W. ¼ sec. 2, 64–3 the gabbro contains parallel bands of magnetite which dip S. 40° and give the rock a decidedly stratified aspect. Some of the beds or bands of magnetite are four or five inches thick, others only a fraction of an inch. No. 442.

The gabbro on the south side of Tucker lake presents a basaltic structure. It is very coarse and the planes of intersection are nearly at right angles with each other. One set dips S. 20° W. 45°; the other set is vertical. The gabbro here is unusually biotitic. It also contains white feldspar equal in amount to the labradorite in places. No considerable amount of magnetite was seen around the lake. It was all mixed in with the gabbro.

The point that runs through sec. 35, 65–3, on Loon lake, is highest in the N. W. ¼ sec. 35. It is made up of hills of Animike capped by trap or fine gabbro. There is here a thickness of about 150 feet of black Animike slate dipping S. 30° or more, and 30 feet or more of trap rock on top. The slate and trap are represented by 443 and 444 respectively. There is a gradual transition between these two rocks, the slates having been somewhat metamorphosed. Large pieces of coarse porphyry are seen on top of this hill. One large mass had trap rock stuck fast to

This rock is a phase of the gabbro. Some of it is fine and hard and very tough. It is composed of hornblende, biotite and red feldspar. A little farther south the rock is coarser and contains a small amount of gray labradorite. Then the two kinds of feldspar occur in equal proportions. From here the red feldspar fades out until the usual condition of the gray gabbro is reached. Where the fine, hard, reddish-black rock is first seen it does not look at all like gabbro. Nos. 425 to 425 C illustrate the change.

Hornblendic gabbro is seen in a low exposure not far east of the north end of the lake. No. 426.

This lake is situated in secs. 20, 29 and 28, 60–6. Very few exposures of rock are seen around it, the shore being mostly composed of the drift which supports such a fine growth of pine. Hills of drift 60 feet high surround the lower end of the lake. A few boulders are seen on the lake shores, but they are mostly sandy. There is an immense accumulation of boulders just north of the lake — large bare ridges of all sorts of boulders, trap, gabbro, Cupriferous, Keewatin, porphyry, granite and Animike slate. These ridges are evidently morainic deposits.

A short portage of 285 paces leads southeast from lake Harriet to Pine lake just east of it. Some trap and a peculiar rock of various colors and texture were seen on this lake. The notes here were taken by Mr. Grant.

A half mile portage leads across the divide from Pine lake to a small, nameless lake 30 feet lower. No rock was seen around this lake.

A long portage, over two miles, leads south to *Kapokegamak or Crooked lake*, in Twp. 59–6. The country is all covered with a fine growth of green timber. The drift is rich and evenly distributed and the land is good for farming.

In sec. 15, 59–6 some fine-grained, olivinitic gabbro was found. It is cut by extensive dykes of green trap.

A sample of gabbro which was found in place on the west side of Crooked lake is 428. Steep hills of trap occur just west of the northern narrows, sec. 15, 59–6. This trap is porphyritic with green feldspar(?). It outcrops in several spots around the lake south of here. 429. Glaciation is N. 6° E.

From Crooked lake a short portage leads south to a small nameless lake on which no rock was seen. From here a portage of one-half mile leads to Nine Mile lake, so-called because it is nine miles by trail to lake Superior and no more canoeing. On the north and west sides of this lake are exposures of rather fine-grained, olivinitic gabbro. 430.

Following the nine mile portage trail south a distance of one mile a small pond less than one-fourth mile long is encountered. This is 75 feet lower than Nine Mile lake. In the next half mile the trail rises 220 feet and reaches a pond 205 feet above the last small lake. Lake Superior can be seen from the hills surrounding this pond, which rise 75 feet above it. The land on the south shore of the great lake can also be seen with the naked eye. This pond is supposed to be in sec. 35. 58–6.

The creek which flows from the pond runs in a deep gorge. The east wall of this gorge is Cupriferous and the west wall is fine-grained olivinitic gabbro or trap. This is the first true Cupriferous seen on this route. It rises in high, precipitous hills consisting of a reddish felsitic rock very much jointed and containing light and dark spots and streaks. Several shafts have been dug at the foot of the gabbro ridge on the west side of the gorge mentioned above. Fragments of the reddish Cupriferous rock were thrown out from all of these pits; and in fact that is apparently the only rock found in digging them. In one of these shafts the red rock seems to be in place. This is just below the lofty bluff of gabbro which therefore seems to lie upon the Cupriferous here. Still they may be side by side and neither one be above the other. The gabbro contains more olivine and less magnetite than that seen six miles north of this place. The general boundary line between the gabbro and Cupriferous runs through the south tiers of sections in the east half of township 58–6. Samples of the gabbro are 431. The Cupriferous is 432.

Between this high ridge and the range of hills just north of the lake there is a low, broad valley heavily timbered. The trail does not cross the highest part of the ridge along the lake shore, but follows the valley of a small stream which seems to have cut a gorge through the ridge, but probably followed a natural depression. No rock was seen exposed south of the gabbro ridge. The trail descends 1125 feet between the small pond mentioned last and lake Superior. There are hills around this pond 100 feet high, and the gabbro ridge is therefore 1225 feet by aneroid above lake Superior, or 1827 feet above sea level. This trail comes out at Pork bay. The hills at the west side of this bay rise 330 to 460 feet above the lake.

GUNFLINT LAKE.

A small stream from the north enters the east end of the lake just north of the boundary river. A few rods west of the mouth of this creek gabbro is seen lying in Animike slates. About one-eighth of a mile up the creek rock in place is noticed. This is a ridge of vertically bedded rock supposed to be Keewatin. Strike is N. 80° E. Dip is not constant. Some of it is fine-grained and flinty and resembles the Knife lake rock. 433. Farther up on the east side of the creek the same rock is coarser and not so siliceous, but contains chlorite or sericite. No. 434.

It was because of reports of red jasper being found here that a visit was made to this creek. This jasper was found to be in beds of Animike lying horizontally on the opposite side of the bed of the creek from the Keewatin. The bed of this stream lies in the line of contact between these two formations. The Animike is flinty and becomes more reddish farther up the creek, 435.

About one-quarter of a mile up the stream the creek spreads out into a marshy lake. A north and south Canadian survey line between 297 T and 298 T crosses the creek at the head of the rapid water. At this place, on the east side of the stream, are thick beds of horizontal Animike. It has here the nature of a somewhat decomposed, fine, dark conglomerate. The pebbles in it are iron rusted; they are sometimes an inch long, but generally less than half an inch. They are flattened horizontally, 436. On a knoll above this conglomerate, a short distance east of it is found another outcrop of schistose Keewatin. It is greenish and somewhat sericitic, 437.

In the bed of this same creek there is found the contact between Keewatin and Animike. The two rocks are very similar in appearance and texture at the point of contact, and it is only by following up what is plainly Keewatin on one side and what is known to be Animike on the other until they come together that the junction could be determined. Even then the actual line of contact could not be seen, being in the bed of the creek of running water; but a person can stand with one foot on rock that is plainly horizontally stratified and is magnetitic, and the other foot on a slightly different rock that is lighter colored, contains no magnetite and has vertical bands of sedimentation. The space between is occupied by rock that may belong to one formation or to the other and is somewhat broken up. The best place to observe this contact is at the water's edge on the east side of the brook. The Keewatin strikes N. 80° E. and has a high dip to the north or is vertical; a little farther down the creek, however, it dips S. 75°. A ridge of the Keewatin on the east side of the stream rises above the Animike which lies unconformably in almost flat beds upon and against it. The Animike is 438. Specimens of the Keewatin are 439.

Going south from Gunflint lake to Loon lake a ridge of gabbro 300 feet high is crossed. Loon lake is 195 feet above Gunflint by aneroid. Mayhew lake is 110 feet above Loon lake. It is surrounded on the west side by low gabbro hills. This gabbro contains considerable magnetite. Several claim cabins are located on this gabbro ore. The gabbro in Tucker lake just west of Mayhew lake is also magnetitic. It is quite coarse and decayed and presents a gneissic or foliated appearance. A sample from N. E. ¼, N. W. ¼ sec. 2, 64–3 is 440. In the S. W. ¼, N. W. ¼ same section there is some fine dioritic looking gabbro which also contains magnetite. 441. This lake being 305 feet above Gunflint it is not likely that there is any Animike exposed on its shores; and indeed none was seen.

In the S. E. ¼, N. W. ¼ sec. 2, 64–3 the gabbro contains parallel bands of magnetite which dip S. 40° and give the rock a decidedly stratified aspect. Some of the beds or bands of magnetite are four or five inches thick, others only a fraction of an inch. No. 442.

The gabbro on the south side of Tucker lake presents a basaltic structure. It is very coarse and the planes of intersection are nearly at right angles with each other. One set dips S. 20° W. 45°; the other set is vertical. The gabbro here is unusually biotitic. It also contains white feldspar equal in amount to the labradorite in places. No considerable amount of magnetite was seen around the lake. It was all mixed in with the gabbro.

The point that runs through sec. 35, 65–3, on Loon lake, is highest in the N. W. ¼ sec. 35. It is made up of hills of Animike capped by trap or fine gabbro. There is here a thickness of about 150 feet of black Animike slate dipping S. 30° or more, and 30 feet or more of trap rock on top. The slate and trap are represented by 443 and 444 respectively. There is a gradual transition between these two rocks, the slates having been somewhat metamorphosed. Large pieces of coarse porphyry are seen on top of this hill. One large mass had trap rock stuck fast to one side of it. This rock was not seen in place here, but evidently belongs in the vicinity. Nos. 445 and 445 A. are the porphyry and trap. The Animike here appears remarkably thick and the gabbro on top of less depth than supposed.

In the N. W. ¼, N. W. ¼ sec. 23, 65–4 is a pit 12 feet deep which goes down through highly magnetitic beds of Animike for nine feet and then into the granite. This is nearly as high as the top of the Giant's range. The Animike is fine-grained and contains less olivine than that south of Birch lake, but has very much the same general appearance and lies like it, in strata dipping S. 15° to 30°. The best ore here is quite pure. About four feet thickness of this good ore is seen at the top of the shaft. 446. This ore possesses very strong magnetic properties. The beds of Animike which lie upon or closely above the syenite and granite seem to be very generally ferruginous and sometimes excellent ore.

The rock of the Giant's range here is very similar in texture to that south and west of Birch lake,—only it seems to contain mica here instead of hornblende. The gneissic structure, however, the color and the abundance of large bluish grains of quartz are suggestive features and remind one instantly of the Giant's range at Birch lake and at Hinsdale.

Gunflint lake to Ogishke Muncie. In the N. E. ¼ sec. 25, 65–4, just at the upper end of the first portage on the river above Gunflint lake is a bluff of Animike slates on the south side of the stream, 75 feet high. The northern face of the bluff is perpendicular, exposing finely the edges of the nearly horizontal strata of black slate. This bluff of slate is seen to lie upon trap rock into which it grades by the metamorphism of its lower beds. This trap or greenstone extends in a bare exposure for 20 rods or more north of the river. It is seen to be at least ten feet thick and has a surface dip the same as the slate beds. In some places it is porphyritic with white feldspar in spots or streaks: it then looks like the porphyry, 445, found south of Loon lake. There is a great exposure of this massive rock here, and it is plainly seen to run under the slate bluff. Some of the Animike is a breccia containing angular pieces of some sedimentary rock and of a crystalline rock as large as six inches in diameter.

The greenstone which is probably part of the Keewatin, is cut by a fine trap dyke 8 to 15 inches wide, exposed for 150 feet running N. 10° E. It contains pieces of the Animike or some other sedimentary rock. Two or three smaller dykes run at right angles to this one. Nos. 447 to 447 H are from here, also No. 448, which represents the brecciated Animike.

On the trail which runs west through sections 26, 27 and 28, 65-4, no rock other than Animike is seen. The country is elevated, 400 feet at least above Gunflint lake, and yet the nearly horizontal beds of slate are found all the way up to the top. Some of it is quite magnetic, but most of it is dark carbonaceous slate. Boulders of conglomerate apparently belonging to this formation but not seen in place are No. 449. Pebbles of quartzose and feldspathic rocks an inch and a half long are found in this conglomerate.

A diamond drill has been operated on the north side of the creek in N. W. ¼ of sec. 28, 65-4. There has also been made a cross cut here up on to the hill. The beds of Animike slate and olivinitic magnetite have here a much higher dip than usual, —S. 60° —S. 75°. There is considerable good magnetite here, but the beds are not thick enough to pay for working, 450. The tilted condition of the Animike seems to be accounted for by the rock which lies under it and which rises about 100 feet above it in the ridge north. This rock is a kind of greenstone (Keewatin), in some places looking a little like fine decomposing gabbro, containing considerable biotite at this locality. It contains labradorite and olivine and very little magnetite. The Animike is plainly seen to lie upon this rock which has slightly metamorphosed the nearest or bottom bed of quartzyte and iron ore. The lower beds of the iron bearing formation here are often exceedingly pyritous. Nos. 451 and 452 are from here. The latter number is applied to drill cores from here. These show the gradations and changes of the Animike beds as they become crystalline toward the bottom and pass through metamorphosed strata into the greenstone. The manner in which the drill penetrated the beds of Animike is shown by the following diagram.

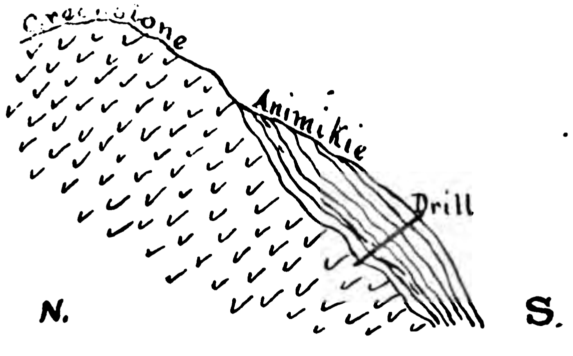


Fig. 8. Animike beds on greenstone. West of Gunflint lake. East of Chub lake.

This greenstone-gabbro ridge runs west of here for several miles, and the Animike is found to lie on it in several other localities much the same as it does here.

Another drilling was made about ½ mile south of the camp in sec. 28, 65–4. Samples from here are 453. These drill cores show the streaks and bands of hornblende crystals which are found in the lower beds of the Animike quartzyte; also the pyritiferous strata. Some of them contain biotite also and are partially metamorphosed into the underlying greenstone. This drilling according to Mr. John M. Millar of Grand Marais, one of the owners of the land, went through the ore in which it started, and about 12 feet into the "north quartzyte;" by which he must mean the underlying greenstone.

The same parties who did the work mentioned above also drilled in the N. E. ¼ sec. 29, 65–4 a short distance west of the first drillings. According to Mr. Millar the record for this working, which is near Chub lake,* is as follows: Quartzyte 36 feet, clean ore 15 feet, mixed ore 17 feet, clean ore 10 feet, greenstone 12 feet. Mr. Millar calls the last "the north quartzyte," but he evidently must refer to the greenstone on which the ore and quartzyte beds lie.

From this record it seems that there is a large quantity of magnetite at this place which will probably prove to be valuable. The parties who own this property are waiting only for the advent of a railroad to commence extensive mining operations. This is the first deposit in the Animike in Minnesota known to be of sufficient extent and richness to repay investment and development.

---

* Mr. Millar states that the name "Akeley" was applied to this lake several years before it was called "Chub lake." No map, however, has been seen to have that name and as it has already been referred to in published reports as Chub lake, the name is retained.

The usual route to Ogishke Muncie was not followed here, but the more circuitous one through the lakes southwest of Chub lake was taken. I can not refrain from stating here by way of parenthesis that the township plat of 65-4 is the most unreliable of any it has ever been my misfortune to be misled by. The lakes in the southwest part of the township are delineated by guess-work and very poor at that.

In the N. W. ¼ sec. 35, 65-5 is a knoll of Animike quartzyte. It has an elevation of about 50 feet on the south side of the stream. It dips south about 75° and strikes east and west. It contains thin beds of good magnetite, 454. Across the valley which lies on the south side of it, is found gabbro.

About a quarter of a mile west of the last is a portage of 100 paces around a rapid in the small stream. It is here seen that the knoll spoken of above is a part of a ridge of Animike that is found all along the south side of this marshy stream. On the south side of this portage trail, N. W. ¼ sec. 35, 65-5, is a precipitous bluff about 40 feet high, facing north. The lower half or perhaps one-third of this bluff consists of greenstone similar to that north of Chub lake, but containing less biotite. The upper half or two-thirds is Animike quartzyte and iron ore tilted up so as to dip S. 70° or more and striking about east and west. There is an abrupt line of contact here shown to exist between the quartzyte and the Keewatin (?) greenstone and the impression made upon an observer of the situation is that the greenstone is the cause of high dip of the quartzyte and iron ore beds.

This is a very fine contact. The stratified quartzyte is seen for several feet lying directly upon the massive greenstone. At this place then the Animike is but very slightly modified by the igneous rock beneath it, and on that account it seems as though the strata must have been deposited in a horizontal position on the greenstone and that both were folded and tilted at a later period. But at other places east of here a few miles the Animike is greatly metamorphosed so that the line of contact is not discernible, and the greenstone might be supposed to be all modified Animike. The greenstone near the contact is a little finer-grained and less massive than it is two feet below; but no other change is apparent. Specimens of the Animike from the contact are 455. The contact was seen again 150 paces west of this place; but it is not so plainly visible. Samples of the Animike from the western contact are 455 A. Specimens of the greenstone from the eastern place are Nos. 456 to 456 C, taken in order receding from the line of contact. Greenstone from the western contact is No. 456 D.

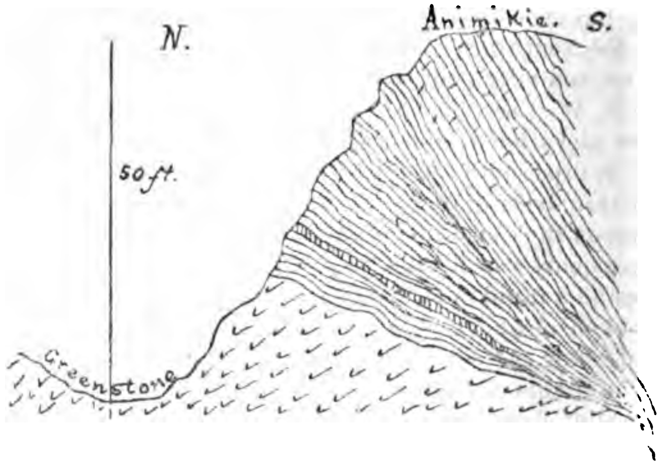


Fig. 4. Animike lying on greenstone, Township 65-5.

At the upper end of the portage are some large masses of greenstone, not in place, which are conglomeritic. Rounded pebbles and boulders of light and dark colored rock—some of them six inches in diameter—occur in it. This rock seemed to be very much like the conglomerate of Ogishke Muncie lake, 457.

On the north side of the creek from the bluff where the contact is seen there is a higher ridge than on the south side. The rock composing it does not appear to be so tough and basic as most of the rock which is subjacent to the Animike quartzyte in this region, 458. It is a fine, greenish-brown, crystalline rock containing feldspar, mica, olivine (?) and a little magnetite.

Iron ore is marked on the plat as existing in large quantities on the line between sections 12 and 13, 64–6. This locality was visited and the rock was found to be magnetitic gabbro. No good magnetite was seen. Some of the gabbro from this place is very coarse and contains coarse hornblende, 458 A.

Gabbro is the only rock found along the shore of Gabemichigama lake for some distance from the N. E. corner sec. 6, 64–5,

459. It is quite fine grained and somewhat decayed. On the south side of the island in N. W. ¼ sec. 6, 64–5, however, was found a bluff of rock rising 20 feet out of the lake, which may be modified Animike. It has gabbro on top and to the north of it. It is apparently not connected with the trap dyke which crosses the point southwest of the island on the main shore.

Iron ore being reported in the S. E. ¼ sec. 1, 64–6, this place was visited. No extensive deposits of high grade or even medium grade ore were found. The rock is gabbro which is ferruginous in spots, 461. A rock was found here, lying under the gabbro, which may be Pewabic quartzyte. It is gray and fine-granular and when decomposed resembles a sandstone. So little of it crops out of the hill here, and it is so covered by debris from above that but little could be learned concerning its relation to the gabbro, 462.

OTTER TRACK LAKE.

Red jasper and vertical magnetitic schists having been reported from this lake a visit was made to it. The lake is surrounded by high hills of siliceo-felsitic rock standing in vertical beds which strike on the average N. 65° to N. 70° E. on the south side of the lake. The strike, however, is not constant in all parts of the region bordering on the lake. In some places near the west end of the lake the evidences of aqueous deposition are unmistakable and exist in the shape of parti-colored bands running through the flinty rock. These bands do not always coincide with the schistosity which is a more general structure and subject to fewer deviations from the usual direction.

In the N. W. ¼ sec. 33, 66–6 the hills are very high, being 290 feet above the lake by aneroid. Near the lake the rock is feldspathic and graywackenitic. Farther south it becomes almost aphanitic and is flinty. One sample which shows a conglomeritic aspect of this rock is 463. A sample which is very much like the magma of the Ogishke conglomerate is 463 A. Other specimens showing the graduation into flint are Nos. 464, 464 A and 464 B.

In the bottom of the valley in N. W. ¼, N. W. ¼ sec. 33, 66–6 some of the rock is magnetitic. It stands like the rest of the rock and the ferruginous strata are very limited in extent. 465. Up on the hill east of the last are seen a couple of short twisted jaspilyte beds inclosed in the rock. They are not over a foot or

[illegible]

crumpled mass of jasper and magnetite should occur in the green schists here and have no continuation in the line of strike nor any connection with the Keewatin. Samples of the jaspilyte are 469. The magnetite is 469 A. Specimens of schist and jaspilyte from a contact are Nos. 470 and 470 A. The strata in the jasper and iron cliff are generally less than half an inch thick but sometimes a stratum of jasper two inches wide is seen. Glaciated surfaces are observed on the side walls of these bluffs both at top and bottom.

The following figure shows how the jaspilyte beds are crumpled.

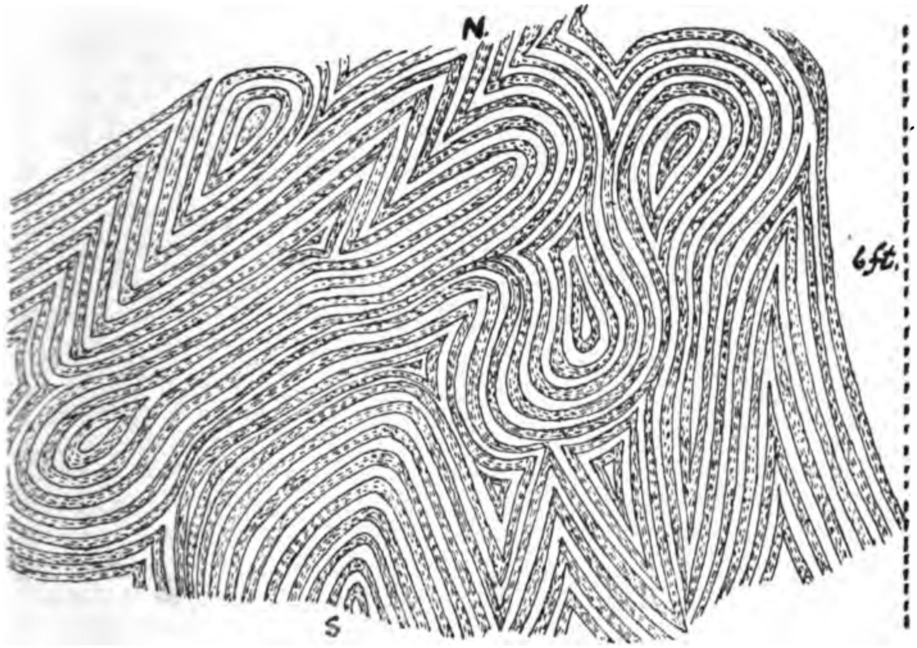


Fig. 5. Distorted beds of jaspilyte; north shore Otter Track lake.

There is a trail running north from Otter Track lake about one mile and a half from the western end. The country is surveyed and good lines are cut. The hills crossed by the trail are very high, some of them being the most elevated land in the entire region, commanding a view of the country for miles around. They are all heavily timbered and have some good white and Norway pine.

eighteen inches wide and but a few feet long. They stand vertical. The iron ore in them is magnetite. No. 466. The contact between the jaspilyte and Keewatin is abrupt. 466 A.

On the north side of Otter Track lake in what would be the N. W. ¼ sec. 27, 66–6 if the U. S. survey lines were extended across into Canada, is a perpendicular bluff of rock 120 feet high and rising still much higher a short distance back from the lake. This bluff consists of sericitic or chloritic schists in vertical beds —as far as any bedding was observed—and striking N. 75° E. At the top this rock is seen to be a coarse green agglomerate like that in the Keewatin at Long lake, made up of coarse boulders of the same material as the formation in general. It is also calciferous, and the boulders are amygdaloidal, particularly around their periphery. In fact the rock is macroscopically identically the same in every respect as that around Ely. Samples of the boulders which contain amygdules are 467. Specimens from boulders which were not amygdaloidal are 467 A. The rock between and around the boulders is calciferous and sometimes quartzose, and is very frequently a breccia, 468. This rock appears very much like the regular Keewatin schists which grade into it in this region and which grade in the other direction into the fine vertically bedded siliceous rock of Knife lake, and the same rock on the north side of this lake both of which show indisputable sedimentary banding. It is impossible to separate or distinguish a line of separation between these rocks. They grade conformably into each other.

Just east of the perpendicular bluff mentioned above, the bluffs are lower. The next one east is a cliff of magnetitic jaspilyte. The beds of ore and jasper are very much crumpled and distorted; but in spite of the folding and doubling the strata are always nearly vertical. The jasper is colored various shades of red to nearly or quite black, and the iron ore does not amount to much. There is, however, a large body of these iron schists inclosed in the green schists here, the jaspilyte continuing for 100 paces along the shore and 40 paces back from the brow of the cliff. The green schist runs into and around parts of the jaspilyte in long elbows and tongues. The contact between the two was seen in several places. It was always abrupt and vertical and the change was not gradual but immediate from one to the other. The contact lines are in all directions of the compass. The jasper soon becomes narrower and stops suddenly at both ends in the line of strike. It is a little peculiar that such a crumpled mass of jasper and magnetite should occur in the green schists here and have no continuation in the line of strike nor any connection with the Keewatin. Samples of the jaspilyte are 469. The magnetite is 469 A. Specimens of schist and jaspilyte from a contact are Nos. 470 and 470 A. The strata in the jasper and iron cliff are generally less than half an inch thick but sometimes a stratum of jasper two inches wide is seen. Glaciated surfaces are observed on the side walls of these bluffs both at top and bottom.

The following figure shows how the jaspilyte beds are crumpled.

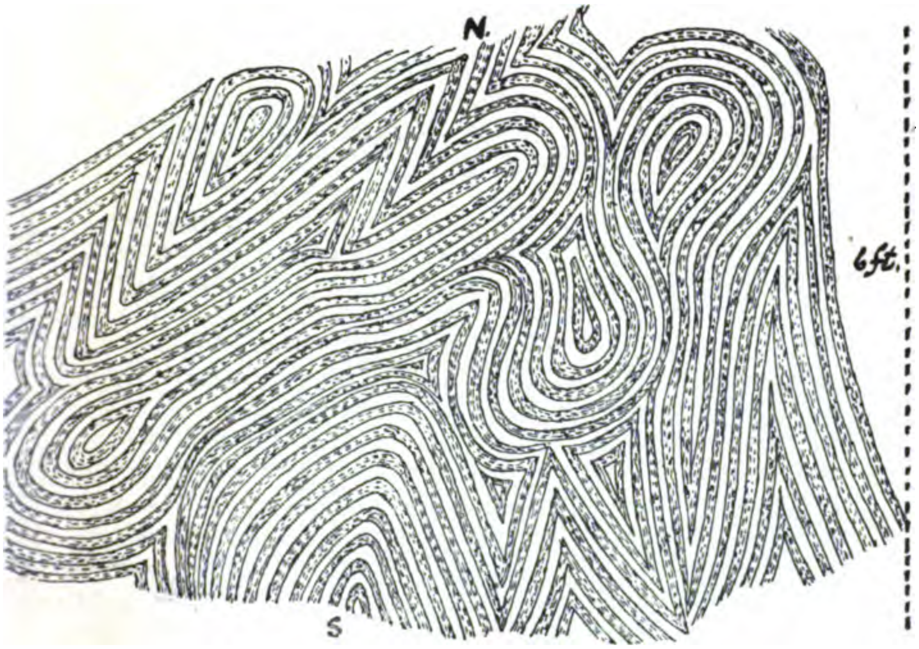


Fig. 5. Distorted beds of jaspilyte; north shore Otter Track lake.

There is a trail running north from Otter Track lake about one mile and a half from the western end. The country is surveyed and good lines are cut. The hills crossed by the trail are very high, some of them being the most elevated land in the entire region, commanding a view of the country for miles around. They are all heavily timbered and have some good white and Norway pine.

The rock is the same for at least a mile and a half north of the lake. That is, it all belongs to the same formation, supposed to be the Keewatin. It stands in vertical beds which strike N. 50° to N. 75° E. Some of it is quite finely schistose and chloritic and some becomes hard and feldspathic and semi-crystalline. A tough, green sample of the latter kind of rock is 471. It is from the corner marked "R 333" and "R 337," about half a mile north of the lake.

One high ridge consists of this green rock in a porphyritic state. The feldspar crystals are large but are not pure nor angular in shape. In fact they appear more like rounded lumps of white felsyte, but are evidently crystalline. Samples of this rock from the north side of a lake about half a mile long which lies near Otter Track lake on the north, are 472.

Coarse agglomeritic greenstone similar to that at Ely was also seen here. It always presents the fine amygdaloidal cavities and small calcite amygdules around the peripheries of the boulder forms inclosed in it.

In many places north of this lake there may be seen beds of red and black jasper and magnetite enclosed in the green rock. These deposits vary in extent and in the richness and purity of the ore which they contain. Sometimes the rock itself seems to fade into jasper and to become ferruginous and banded. At other times the rock is quite massive in appearance and has an abrupt contact with the enclosed masses of jaspilyte. The fact that some of the jaspilyte beds seem to graduate into the green rock seems to afford some support to the theory that some beds of the Keewatin formation are ferruginous, and that owing to their different composition they were not rendered hard, massive and semi-crystalline nor soft and schistose by the heat and pressure attendant upon the folding of the earth's crust, but present the evidence of having been subjected to these same forces and influences in the crumpled condition of their strata. It is very seldom that the beds of jaspilyte are straight for any considerable distance. They are almost always folded and bent as in the foregoing diagram.

Samples of the rock which seem to be grading into red and black jasper are Nos. 473 and 473 A. A sample in which the magnetite appears in the green rock and not in jasper is 473 B. The jaspilyte is 474. An average sample of the non-schistose variety of this rock is 475.

This green rock is all very much jointed and decayed far into the seams and it is difficult to obtain fresh samples. No extensive iron ore deposits were seen. The beds of jasper and magnetite all seem to be quite limited in extent both as to length and thickness, and what there is, is at least half jasper and the other half but poor iron ore.

LAKE VIRA.

This lake is reached by a portage of 900 paces from the southwest end of Knife lake. It lies in sections 1, 2 and 3, 64–8 and is surrounded by vertical schists and argillytes. A sample of argillyte from the N. W. ¼ of S. E. ¼ sec. 2, 64–8 is a fair illustration of most of the rock surrounding this lake, 476. The strike is N. 80° E.: dip at a high angle to the north: glaciation N. 40° E. This lake does not differ much from Knife lake in hight: but it is 40 feet by aneroid above Ensign lake into which it flows by a good-sized stream.

There are high precipitous bluffs of schist and graywacke at the west end of the lake. We cut a portage of 1150 paces from lake Vira to Ensign lake. The country between Knife lake and Vira lake is burnt over, but that from Vira lake to Ensign lake is covered with green timber.

In the N. E. ¼ sec. 10, 64–8 on Ensign lake the rock is a soft, fissile argillitic schist showing no bands of sedimentation but having a wavy schistose structure trending N. 80° E. The dip is about vertical or at a high angle to the north. Glaciation is N. 24° E.

DISAPPOINTMENT LAKE.

This lake is reached by a portage of 1150 paces from Snowbank lake. There are two other ways to reach it by good portage trails. The physical aspect of the country around this lake is quite different from that around Snowbank lake. It is in a burnt region where the bare and dead tree trunks are still standing. This lake is 75 feet by aneroid above Snowbank.

About 450 paces from Snowbank lake a ridge of mica schist is crossed by the trail. The mica is in small glistening scales. The strike of this schist is N. 45° E. A sample from S. W. ¼, S. W. ¼ sec. 32, 64–8 is 477.

This mica schist is cut and penetrated by intrusions or veins of fine-grained, red granite. This appears in the next ridge east of last, 478. Large masses of conglomeritic mica schist appear here on the surface but do not seem to be in place. This rock however is found *in situ* at the east end of the portage in S. E. ¼ sec. 32, 64–8. The schist is hornblendic and appears to be hardened. It is full of boulders of various kinds of crystalline rocks in masses of all sizes up to a foot in diameter. There is a great deal of this rock here. No. 480. A sample of mica schist from here which is not from conglomeritic beds and is more schistose than that which is, is 479. The conglomeritic mica schist is also penetrated by the red granite intrusions. 480 A. These are of all thicknesses up to 20 feet and run in all directions.

There is a dyke of trap rock on the north side of the portage at this lake. It is about 10 feet wide, and runs N. 30° W., 481. The strike of the schists here is not that of the formations generally in this region. It varies from N. E. and S. W. to N. and S. In the N. W. ¼ sec. 5, 63–8, the strike is N. 16° E.

The schist is decidedly conglomeritic in the N. E. ¼ sec. 5, 63–8. Most of the boulders are lenticular, but many of them are nearly round. The general strike, where there is any strike apparent, is N. 30° E. One sample of finely conglomeritic mica schist is 489.

In the S. ½ N. W. ¼ sec. 4, 63–8 the mica schist seems to undergo a decided change, going east along the lake shore. It becomes less schistose, contains less mica and occurs in hills and knolls of uneven hight which do not display any strike or evidence of sedimentation or schistosity. In the S. E. ¼, N. E. ¼ sec. 4, 63–8 the rock does not seem to contain any mica, but is a fine-grained, grayish-brown rock like what has been termed in some former reports of this survey "muscovado." It lies in round-topped knolls which have the shape and appearance, at a little distance, of gabbro hills. Some of it is peculiarly mottled.

Going south from Disappointment lake into the N. E. ¼ of S. W. ¼ sec. 4, 63–8 a ridge of magnetite and quartzyte is crossed. It is about ten rods wide: the strata stand nearly vertical and strike, as nearly as could be estimated, for the needle is reversed, N. 70° E. This rock is supposed to be Animike. It is olivinitic and fine-grained and the iron ore is brilliant and granular and very magnetic like the other ore from the same horizon. The only reason for doubting that it is Animike is that it stands on edge and has the "muscovado" or altered mica schist on the north of it.

Mr. H. W. Cheadle owns a claim here. He has done some stripping which gives a good section of the rocks up the slope of the hill. Fine-grained gabbro is seen lying on the up-turned edges of the iron ore beds. This forms a small ridge. The next ridge to the south is composed of coarse gabbro containing a large per cent of titaniferous (?) magnetite. South of here are high ridges of this same gabbro. Nos. 490, 490 A and 490 B show the transition from mica schist to muscovado; 491 is the Animike iron ore and quartzyte. This rock is much decayed and broken. It has suffered the effects of frost and forest fires as well as of upturning, gabbro overflow and glaciation. Fine-grained gabbro from on top of the ore beds is 492. Coarse gabbro is 493. There is quite a deposit of good magnetite here which may prove to be valuable.

The muscovado schist or rather the mica schist has somewhat the aspect of an altered igneous rock. It is not regularly schistose nor very micaceous but is full of holes and furrows, etc. The muscovado again grades into mica schist which is so feldspathic as to be almost gneiss, east of here. It is also generally conglomeritic; in some places almost entirely composed of small pebbles and boulders, in others not any being seen. Specimens of this rock from the N. E. ¼ sec. 4, 63–8, are numbered 494.

The mica schist in the S. W. ¼ sec. 34, 64–8 approaches gneiss in texture and composition. It is hardly at all schistose and in places is almost massive but has the cleavage and color of mica schist. It contains fine hornblende crystals. Some of it is firm and brittle and may be called fine syenite, 495.

In the S. W. ¼ sec. 34, 64–8 the mica schist becomes much more regular and loses its conglomeritic aspect. It is hard and fine-grained. No definite and permanent strike or dip is discernible.

Near the west quarter post of sec. 34, 64-8 the mica schist has a kind of structure which runs N. 10° W. It also becomes conglomeritic, containing flattened boulders of granite and other varieties of crystalline rock eight inches long. The longer axes of these boulders point N. 10° W. This is regular mica schist conglomerate not like the many boulders and fragments of diabasic and porphyritic agglomerate which abound in this place.

There is a great exposure of conglomeritic mica schist in the N. E. ¼ sec. 33, 64–8. It all has a general strike N. 10° W., and seems to be regular mica schist, 496.

In the N. W. ¼ sec. 34 and the S. W. ¼ sec. 27, 64–8 there is a most wonderful exhibition of conglomerate and diabase. Going east from the point in the N. E. ¼ sec. 33 the conglomeritic mica schist becomes coarser and more full of boulders. These consist of various kinds of light-colored crystalline and dark hornblendic rocks; and are many of them a foot long. The mica schist gradually becomes harder and less siliceous until it is diabasic. East of the lake there are high ridges rising 75 to 150 feet above the water. These become more and more diabasic until they culminate in a high ridge of nearly massive diabase about a quarter of a mile from the lake. There is a coarse schistosity seen in this ridge in places. The strike of the rocks as shown by the schistosity, the direction of the longer axes of the boulders and the foliation of the mica schist are all *about northwest.* These ridges offer one of the finest exposures of conglomerate and agglomerate seen in this entire region. The rock in places is just as full of boulders as it can be. These become smaller and more compressed toward the east, and disappear altogether in the vicinity of the diabase ridge. Some of the diabasic schist is porphyritic. Samples of the conglomerate are 497. Diabasic schist is 498. Diabase is 499. Gneissic schist from the edge of the lake showing foliation which was northwest is 500. Biotite schist from a well-defined dyke about a foot wide which cuts the diabasic agglomerate, running about east and west, is 501.

It is quite remarkable that there is here a gradual transition from mica schist to diabase. There is no place where there is an abrupt change. The mica schist is conglomeritic and the diabase is agglomeritic. They are both schistose and have the same trend and seem to be vertical, as far as bedding is indicated by foliation and schistosity. It is a very thick conglomerate too: fully two miles across the strike. No attempt will be made to account for this transition here nor to prove whether there are two conglomerates here or not.

In the N. E. ¼, S. W. ¼ sec. 27, 64–8 the rock is very fine and even-grained, and so siliceous as to be flinty, 502. Glaciation is N. 34° E. No regular bedding or schistosity is seen here.

In the north end of the bay in the S. W. ¼, N. W. ¼ sec. 27, 64–8 the siliceous rock becomes porphyritic with small imperfect white and yellow feldspar crystals. It is indistinctly conglomeritic in places and is coarsely schistose, 503. Large masses of hydro-mica schist are seen here and indicate beds of this rock in the vicinity.

West of here the rock becomes a porphyritic conglomerate and in places over quite a wide extent is micaceous porphyritic conglomerate. Many of the included boulders are more porphyritic than the magma. The strike is N. 10° W. All of this rock is more or less hornblendic. Around the lake shores the rock is peculiarly pitted and full of holes where some of the softer boulders have been washed out. No pieces of red jasper were noticed in this conglomerate, such as are seen in the Ogishke Muncie conglomerate. Wherever the rock is decidedly micaceous it is intersected and penetrated by *red* granite or syenite intrusions. This is especially the case on the large island in the S. E. ¼ sec. 32, 64–8.

ROUND LAKE.

This body of water lies west and southwest from Disappointment lake, the waters from which flow through Round lake before reaching Snowbank lake. It is 30 feet lower than Disappointment lake, and is reached from it by a portage of 540 paces. Mica schist is seen on the trail. It is more feldspathic and compact or gneissic than that farther northeast. In the N. E. ¼ sec. 6, 63–8 the mica schist changes to gneiss or syenite gneiss. There is but a small quantity of this rock here, however, most of it being a mixture of mica and hornblende gneiss and mica schist. The beds have been considerably crumpled so that no general strike is observable. A sample of mica schist from the S. E. ¼ of N. E. ¼ sec. 6, 63–8 is numbered 482. Syenite gneiss from the N. W. ¼, N. E. ¼ sec. 6, 63–8 is 483.

The west side of Round lake has syenite around the shores. This becomes dark and siliceous and changed into a peculiar rock that seems to have been affected by the proximity of some igneous rock or other metamorphosing agent. 484.

In the N. W. ¼, N. E. ¼ sec. 7, 63–8 the syenite lies under a hill of gabbro which has a bold face on the north side nearly or quite 100 feet high. This syenite is sometimes micaceous enough to be called hornblendic gneiss. It has been somewhat broken up here and the contact between it and the gabbro is not visible. The latter rock is somewhat finer near the contact with the syenite than at the top of the hill. Syenite is represented by 485: the gabbro by 486.

In the S. E. ¼ sec. 6, 63–8 the rock is mica schist hardened by the vicinity or contact of the gabbro. The gabbro ridge runs south of the lake and really does not appear at any point on the lake shore. Samples of mica schist from the above-mentioned locality are 487. Some of it is flinty and has very little if any mica in it.

To the northeast of the last is a knoll of fine red quartzyte or syenite. It is probably part of a large intrusion in the mica schist. 488.

The mica schist in the southeast part of section six is much twisted and varies greatly in its strike and in the composition and texture of its strata. Some are hard and siliceous and others are soft and iron-stained. It is cut by numerous veins or intrusions of granite and is slightly conglomeritic in places.

TOWNSHIP 63-9.

On the portage trail from Snowbank lake to the Kawishiwi river gneiss and mica schist are seen in a few outcrops within three-quarters of a mile from Snowbank. About a mile from the lake the trail passes within ten feet of a bluff of gabbro which faces east. This is in the S. W. ¼ of S. W. ¼ sec. 11, 63-9. The rock is the regular coarse labradorite gabbro. About 200 paces south of this gabbro, on the section line between ten and eleven is found a ridge of biotite, olivine schist. This has the usual strike, N. 60° E. and dips S. 75°. It is conglomeritic in many places and bears a striking resemblance to the conglomeritic mica schist found at the southeast corner of Disappointment lake. 504.

A ridge of gabbro is again crossed 450 paces south of the N. W. corner sec. 14, 63-9. This is a high ridge with a steep bluff of the coarse light-colored gabbro on the north side. Three hundred paces farther south the rock is all "muscovado" in a great ridge. No structure or bedding of any kind is visible in it. It is simply in large hills and ridges, and is fine-grained and homogeneous in texture.

A short distance north of the "quarter-post" between sections 14 and 15 this ridge of muscovado is bounded on the south by a swamp. Along the south side of the ridge, next to the swamp, is a considerable deposit of magnetite. It is the regular coarse, dull-lustred, gabbro magnetite. The rock can not be distinguished from the gabbro nor from the muscovado either. Number 505 is the muscovado. 505 A is the magnetite.

The Kawishiwi is about 12 feet above Snowbank lake where the portage from the lake strikes it. The trail passes across and by the side of gabbro ridges for half a mile before reaching the river.

Going north on the west line of sec. 16 the gabbro disappears a short distance north of the river. The rock next north of the gabbro is the muscovado-like mica schist with the usual strike and vertical dip. It is conglomeritic a short distance farther north and is hornblendic like that on Disappointment lake. It loses its similarity to muscovado and becomes regular mica schist, though more or less gneissic and conglomeritic, about the west "quarter-post" of sec. 16. Sample is 506.

At 340 paces north of the "quarter-post" mentioned above, a swamp intervening, a ridge of diabase is encountered. This runs along the north side of the swamp in a N. E.-S. W. course. It is probably part of the same diabase eruption as that east of Disappointment lake, 507. Many fragments of porphyritic conglomerate are seen lying about on the surface at this place.

This ridge keeps on rising with a gentle slope until its summit is reached at the N. W. corner of section 16. From here the descent is gradual toward the north, but not so gradual as on the south side. The diabase is massive for some distance from the place where it was first seen. Then it begins to show a coarse schistosity and has a coarse agglomeritic appearance as in the rock at Ely, the boulders being all of greenstone and indistinctly outlined on the surface. The rock is strikingly similar to the Ely rock as far as the agglomeritic appearance goes; but is not soft and chloritic like that, nor does it appear to be calciferous. It is simply regular diabase, 508.

At 375 paces north of the southwest corner of section nine the diabase has changed from a massive rock to a fine, schistose, diabase agglomerate. The direction of the very evident schistosity as well as of the lenticular pebbles of greenstone in it, is E. 16° S. This is on the northern slope of the great diabase ridge, and the rock has been examined at many places so there is no doubt as to its being part of the same diabase. The coarse agglomerate has become a fine schistose pudding-stone and is rapidly changing into green chloritic schist toward the north. Samples of diabase conglomerate are No. 509.

This fine greenstone agglomerate continues to be exposed for some distance toward the north. The direction of the schistosity swings around to N. W. and S. E. which is the general direction of it in sections 8 and 9.

Some distance south of the east "quarter post" of sec. 8 a ridge of porphyritic rock which contains grains of vitreous quartz is encountered. It is a light colored rock and when first seen it appears perfectly massive. It has an abrupt contact with the diabase which is also more massive at this place. The porphyry appears to run in N. W.-S. E. ridges. North of here it is seen to be mixed up in every way possible with the diabase and finally, in the N. E. ¼, N. W. ¼ sec. 8, becomes the prevailing country rock.

Toward the north still farther this porphyry becomes coarsely schistose and acquires more of the green uncrystalline elements. It also loses its decidedly porphyritic aspect as the distance from the diabase ridge increases. It is slightly conglomeritic; in one place red jasper was seen in it and in another a pebble of greenstone. Nos. 510, 510 A and 510 B show these various conditions of the porphyritic rock.

The diabase continues to abound and ridges of porphyry, or porphyrel and greenstone are strangely mixed up together. In the N. E. ¼ sec. 8 are seen large ridges of jaspilyte, consisting of red and black jasper, hematite and magnetite in crumpled vertical beds running about N. 60° E. After a long and extensive examination the state of affairs seemed to be as follows: There is a large amount of this jaspilyte here. Some of these lenticular masses of jasper and iron ore were traced continuously for half a mile or even more. These masses lie in the diabase and have an abrupt contact with it. Many pieces and masses of jaspilyte of all sizes from that of a pea to the large ridges spoken of above are seen to be enclosed in massive or only slightly schistose diabase, not in any general line of strike, but at intervals separated from each other across the strike by various distances less than a mile.

Sometimes the diabase is quite coarse and appears more like dioryte with white feldspar crystals on the surface.

In some places the porphyry approaches quite near to these jaspilyte masses; but that is not to be wondered at, inasmuch as the ridges of porphyry run all through the diabase without any definite order or direction. This jaspilyte is more hematitic toward the north and west where it is identical in appearance with that at Tower. Places were seen where the diabase is quite schistose at the contact with the jaspilyte and even as soft and greasy feeling as the soft schists in some of the Tower mines. The beds of jaspilyte are nearly as much distorted as at Tower. This diabase is seen on both sides of the iron ore and cutting across the beds. It also seems to contain fragments of the porphyry and becomes porphyritic itself in the vicinity of the porphyry ridges. Specimens of the diabase, which is found enclosing the large and small masses of jaspilyte in the N. E. ¼ sec. 8, are 511. Contact specimens with the jasper are 511 A. Samples of diabase containing small masses of jaspilyte are 511 B. Porphyritic diabase containing a piece of porphyry is 511 C. Samples of the soft sericitic or talcose rock are 512. This rock being so soft is always found in low places and could not be seen to be certainly part of the diabase. Sometimes the rock next to the jaspilyte is not green and does not look like diabase but is gray and somewhat schistose, 513. Samples of the jaspilyte are seen in 514.

The porphyry becomes more and more prevalent toward the N. E. "forty," sec. 8 until there is no more diabase nor jaspilyte. There is, however, a dyke of green trap that runs under Hugh Copeland's cabin in the N. W. ¼, N. E. ¼ sec. 8. It is about 30 inches wide and can be traced for 200 paces or more running about north and south through the porphyry. It is not perfectly straight but curves some and is faulted in two or three places. The course of it is also interrupted at one place north of the cabin by strings and branches from the porphyry mass which make it appear as if they both were plastic about the same time. Sample of the porphyry is 515. The dyke rock is 516.

The above observations are considered to be of importance as they seem to prove beyond doubt that *the jaspilyte beds are enclosed in basic rock of igneous origin.*

This region and these beds of iron ore contain some of the most promising deposits seen during the past season. There is good reason for believing that there are valuable and extensive beds of iron ore in the northern part of this township.

The ridges of diabase and porphyry alternate southeast of Copeland's cabin. A sample of rock composed of a tenacious green mineral is 517.

In some places the diabase is agglomeritic in close proximity to the enclosed masses of jaspilyte, the diabase all around such a mass containing the forms and outlines of greenstone pebbles. There is also conglomerate closely interbedded with this diabase agglomerate and apparently of a later date. It has for a magma the earlier fine agglomerate (?). These two sometimes come into direct contact, standing side by side. No. 520. This later conglomerate contains almost exclusively fragments of the porphyry and of the jaspilyte. It is never very thick and generally lies between the greenstone and the porphyry.

There are occasional tendencies toward a micaceous nature in the porphyry, and a thin stratum of schist bedded by sedimentation is seen here and there, 518.

Some of the fragments of jaspilyte seen enclosed in the greenstone are perfectly white jasper or quartzyte which crumbles into fine grains upon hammering, 519. This also is like the same fine granular quartz beds in the jaspilyte north of Tower.

In only one place was the iron ore and jasper seen in contact with the porphyry. At this place a bed of jasper three inches thick has porphyry on one side and diabase on the other. They come very close together in many places, but in all other cases observed there was a thin wall or flow of diabase between them.

A vertical bluff of greenstone 20 feet high was seen in one place with a thin coating of the light colored porphyry plastered over the entire face of the bluff. A contact specimen from here is 521.

In one place the coarser diabase which when weathered shows small white feldspar crystals on the surface, was cut by a small trap dyke. The coarser, older diabase is 522. The dyke rock is 522 A.

Going north on the line between sections nine and ten the first rock is seen quite near the river. This is fine-grained mica schist which may contain olivine, 523. This rock is conglomeritic in places and particularly in a small ridge not far north of the river. The small enclosed pebbles are compressed with their longer axes pointing N. W. - S. E., 523 A. There is next a ridge of diabasic mica schist, 523 B.

Some of the beds of mica schist are siliceous and felsitic and are iron-stained, 524. At 300 paces north of the S. W. corner sec. 10, there is quite a ridge of mica schist. It strikes N. W. and dips S. W. 70°. Samples showing lines and bands of sedimentation are 525. At 400 paces there is a contact between the beds of mica schist and diabase which latter has been more or less affected by the proximity of the schist and has a less massive appearance than usual. The mica schist too has been somewhat altered; but the change is abrupt and distinct between the mica schist on the S. W. and the greenstone on the N. E.

In this place therefore the mica schist has an abrupt contact with the greenstone and does not grade into it as it appeared to on the east side of Disappointment lake. The schist here seems to have been affected by the greenstone eruption: its strike and schistosity have been bent around nearly 90° from the usual direction. The mica schist has been hardened and rendered more like the diabase so that upon a casual inspection the two might seem to run together. Mica schist from the contact is 526. The diabase is 527. A specimen of peculiar, dark mica schist which has gray figures and lumps like drops of mud all over the surface is 526 A.

This was not the main ridge of diabase but only a subordinate branch or large dyke of it. The mica schist and greenstone seem to have had quite a struggle for supremacy in this region; first one prevailing and then the other. The general strike is N. W. and the dip varies from S. W. 45° to vertical. There is a ridge of coarser diabase in the N. W. ¼, S. W. ¼ sec. 10. It is quite near a contact with mica schist. 528.

In many places the mica schist is full of light gray grains of soft material which weather out and leave the surface of the rock pitted with small holes. This schist is darker and less micaceous than some of the rest, but it always conforms with the general strike and seems to be a part of the general mica schist formation. 529.

The mica schist contains thin beds of green diabasic rock which run with the other beds and are also schistose. These beds are decidedly basic and only a few inches thick, but are quite persistent and maintain their general appearance and width as far as they can be followed. 530.

Going farther north the mica schist becomes harder and more feldspathic and appears to be incipient porphyry, showing how the extensive porphyry belt north of here may be altered mica schist. 531.

Some specimens of agglomeritic diabase in which the pebbles seem to have been pasted together in a very plastic state are 532. The mica schist and incipient porphyry have also a conglomeritic structure though it is rather indistinct.

A little jaspilyte is found enclosed in the greenstone in the N. W. ¼, N. W. ¼ sec. 10. The diabase is softer and chloritic and possesses the coarse agglomeritic or concretionary (?) structure seen in it so often.*

The observations made in going north on this section line simply confirm those made on the line a mile west, and demonstrate that the coarse, chloritic, schistose agglomerate is part of this great diabase eruption and that the jasper and iron ore beds are contained in it.

---

* Report of H. V. Winchell. Fifteenth annual report, p. 404.

A ridge of mica schist is again encountered just south of the quarter post between sections 3 and 4. A large exposure of this rock is found here. It is quite hard and contains a little of the diabasic rock in these beds. 533. Strike is N. 16° W.

At the N. E. corner sec. 4, the porphyry is met with, and is the same in appearance as that found in the N. E. ¼ sec. 8. The relation between the porphyry and mica schist is not evident here, but they seem to have a more or less abrupt contact. Samples of porphyry are 534. The mica schist has been becoming more argillaceous and less micaceous. Here there is a large ridge of it in which the strata are greatly crumpled and the principal strike has been changed to N. 10° E. It here seems that the porphyry is not a part of the mica schist formation, but that it was protruded into the schist beds and caused all of this disturbance. Argillitic mica schist from here is 535.

Going west from here along the north line of sec. 4 a swamp is crossed, and on the west side is found a diabase ridge. Just west of the north quarter post of sec. 4 is more porphyry in knolls and ridges which penetrate and are surrounded by the diabase. They always have an abrupt contact. This porphyry is conglomeritic, containing felsitic and siliceous boulders a foot in diameter. Samples from the S. E. ¼, N. W. ¼ sec. 4 are 536. A basaltic structure is frequently seen in the porphyry.

In the S. W. ¼, N. W. ¼ sec. 4, on the ridge which lies between two small lakes is quite an exposure of red jasper and hematite. This is seen to be in beds of various thickness up to four or five feet, which do not have a common strike. Some strata, enclosed in diabase, strike east and west; while other beds only a few rods away strike E. 30° S. The beds all stand vertical and *are very little crumpled*, 537.

The diabase has a tendency to become coarsely schistose where it lies in contact with the iron and jasper, but farther away it is very hard, tough and massive. It has also a coarse agglomeritic structure, very indistinct at this precise spot, but quite noticeable a short distance east of here, and is chloritic. Nos. 538-538 C represent these rocks.*

---

* An analysis of this green rock, 538 B, made by Mr. C. F. Sidener shows, as was expected, that it is basic. The full record is as follows:

Silica, SiO_2	50.47 per cent.
Alumina, Al_2O_3	18.45 per cent.

There is also some black jasper and magnetite at this place enclosed in the greenstone in the same manner. The beds are thicker and seem to contain purer ore than the hematite beds. No. 539.

Between the N. W. corner sec. 4 and the east quarter post sec. 8 a decided change takes place. The diabase around the south side and west end of the small lake on the north line of sec. 4 assumes a schistose structure which becomes finer and more universal toward the southwest. At first it is a fine agglomeritic diabase schist; then it becomes more and more siliceous until it is flinty and actually resembles the Knife lake rock. From this place, where the rock was found to be very siliceous, a set of specimens was procured from every outcrop south as far as the E. quarter post sec. 8. This siliceous schist stands in vertical beds which strike N. W.–S. E., and sometimes swing around to N.–S. The rock becomes more and more flinty until at the N. E. corner sec. 8 we have the regular siliceous schist of Knife lake. From here south to the E. quarter post sec. 8, this siliceous schist is seen to grade into the porphyry which was found there before. In one or two places the siliceous schist seemed to be going back to diabase; and ridges of diabasic schist and agglomerate were crossed on this line; but they seem to be part of the intruded diabase which comes into contact with this porphyry farther south. Thus we have diabasic schist and even massive diabase becoming siliceous and even flinty and then porphyritic, and finally coming into contact again with another part of itself farther south. Nos. 540–540 J show this transition.

Going east from the N. E. corner sec. 8, mica schist is met with at less than a quarter of a mile. It has an abrupt contact with porphyry. 541.

The mica schist seen in this township is fine-grained, almost always argillaceous, poor in mica, which is always in very small glistening scales, and generally hornblendic.

Sesquioxide of iron, Fe_2O_3	2.13 per cent.
Protoxide of iron, FeO	7.74 per cent.
Lime, CaO	6.61 per cent.
Magnesia, MgO	6.90 per cent.
Potassa, K_2O	.30 per cent.
Soda Na_2O	2.58 per cent.
Phosphoric acid, P_2O_5	traces.
Water, H_2O	2.34 per cent.
	97.52 per cent.

The mica schist formation becomes hornblendic and massive in the N. W. ¼, N. E. ¼ sec. 9. Fine dark syenite from same place is 542.

On the north side of the Kawishiwi river, on the line between sections 19 and 20 the mica schist is only two rods wide. On the north side of it is the coarse diabase agglomerate.

PRAIRIE RIVER FALLS.

A visit was made at the end of the season to Pokegama falls and the region of Prairie River falls for the sake of comparison with and verification of notes made previously.

No new facts were noticed, the report of last year containing all of the points which were noted this season.

Some work is being done east of the lower falls by Minneapolis parties who are searching for iron ore; although no large body of ore has yet been encountered, the prospect is encouraging.

Specimens of magnetic ore were seen at Grand Rapids which came from the property of Mr. Kearny situated about 45 miles north of Grand Rapids in Township 61–24. It seems to belong to the Keewatin and is reported to exist in paying quantities. The locality was not visited.

Mr. Chas. F. Howe, of Duluth, has explored for iron ore in Minnesota for several seasons and is very well posted on the geology of iron ores. He reports the magnetitic quartzyte of the Huronian outcropping in Twp. 59–18. It has the usual dip of about 10° to the S. S. E. and lies near the syenite which is north of it.

The facts and observations given in scattered detail in the foregoing notes if amplified and dicussed at length with all of the careful consideration which they merit would far exceed the limits assigned to this report. But a brief allusion to some points which seem to furnish clues to the solution of a few of the unsettled problems in the geology of this region may be made here without attempting anything like a full discussion or even mention of all the theories upon which the facts before us have a bearing.

The lowest or oldest formation to which these notes make any reference is probably the syenite and gneiss ridge constituting the Giant's range. Observations on this rock were made at various points between Hinsdale, on the Duluth and Iron Range railroad, and Snowbank lake: also at a few localities in the vicinity on what is supposed to be the northeastward continuation of this range. The general characteristics of the rock of this ridge are quite persistent. The vertical foliation, the unusually large grains of bluish quartz which it contains and the general aspect of the orthoclase serve to remind an observer in the Gunflint region of the same features in the rock southwest of Birch lake. Mica, however, frequently replaces hornblende or *vice versa;* and sometimes both are present. Near the surface and for fifteen or twenty feet below, this rock has a reddish or pink color; but at a greater depth it is gray.

A coarse conglomeritic structure is noted in the syenite-gneiss of this range at Hinsdale. Lenticular masses of dark hornblendic rock are seen at all depths in the gray rock at the quarries. These masses are generally more than eight inches in length, and the direction of their longer axes is vertical or nearly so. There is sometimes a foliation or schistosity in these inclusions, and this also is vertical.

A series of vertical crystalline schists is generally found next the older crystallines in other parts of this region; but north and south of the Giant's range at Hinsdale are found exposures of the sericitic or chloritic schists of the Keewatin so close to the syenite as to make it seem improbable that any crystalline schists intervene between them here. If the high ridge is the middle of an anticlinal, as seems to be indicated by the presence of the vertical Keewatin schists on the south side of the ridge, having the same strike as those on the north, what has become of the crystalline schists which lie next above the granites and syenites? Were they so highly metamorphosed and affected by pressure to such an extent that they were incorporated into the more gneissoid rock beneath them, or were they not a widespread and universal deposit? Were there elevated portions of the sea-bottom which were not covered by the sediments from which have resulted the crystalline schists, but which were later covered by the sediments of the Keewatin age? Considering this ridge to be the back-bone of an anticinal the latter supposition seems more probable.

If this be not an anticlinal how can the presence of such an extensive range of crystalline rock in the midst of greenish, chloritic, more or less argillaceous and siliceous schists be accounted for? If the vertical foliation be evidence of some former bedding structure, the only way to explain it seems to be on the supposition that a portion of these schists themselves were metamorphosed by some unusual disturbance along the line of this range, either by the proximity of some great vent below or intense pressure at this place combined with chemical and hydrothermal forces.

The next formation is that already mentioned, the crystalline schist or Vermilion series. I wish to call attention to the fact that in Twp. 63–9 this series of rocks is found to be conglomeritic over a wide area, and has been rendered hard and porphyritic by some adjacent eruption, probably that great diabase outburst of the Keewatin age. Boulders of a large variety of rocks are seen enclosed in the mica schist around Disappointment lake. This fact alone serves to distinguish it from the diabasic agglomerates in which all of the pebbles, with hardly an exception, are of greenstone and jaspilyte.*

In connection with the crystalline schists "muscovado" should be mentioned. It seems probable that this term has been employed in the 15th and 16th reports of this survey, to designate the rotted granular condition of two or three different rocks. Dr. Alexander Winchell has applied it to a rock which he identifies with the Animike. It seems to have been used also to describe fine decayed gabbro as well as an altered condition of gneiss and the mica and hornblende schists.

As far as my observation goes it has been found quite easy to recognize decayed, rusted Animike and fine rotted gabbro such as is frequently found at the northern edge of the gabbro overflow. But in several localities, notably on the south shore of Disappointment lake, there are found large exposures of a granular, yellowish-brown rock which does not possess any distinct signs of bedding or schistosity and which yields to a blow of a hammer much as semi-hardened putty would. It contains fine scales of biotite and grains of feldspar and olivine. It lies at the north edge of the gabbro in rounded knolls which resemble gabbro hills at a little distance, and when its direct connection with the surrounding rock is obscured it can not be recognized as belonging to any of the usual formations of the region nor as being anything but "muscovado."

On the south shore of Disappointment lake there is a great deal of this rock. To the south of it are masses of olivinitic iron ore standing in nearly vertical beds, capped with fine, decayed gabbro and having coarse labradorite gabbro on the south of it. Fortunately the lake shore affords a nearly continuous exposure of this rock in both directions in the line of strike. It was here traced very carefully, on two different occasions, and was found to pass by insensible gradations into mica schist which became more and more micaceous and typical as the distance from the gabbro increased. This mica schist is the northeastern extension of the crystalline schists which are found north of the Kawishiwi river in townships 63–9 and 63–10, and have been followed continuously from there to this lake. The syenite of the Giant's range is known to have formed the northern shore of the Animike ocean. This range is low and narrow at this place and the Animike evidently was deposited on top of the syenite and up to or perhaps upon some of the mica schist which lies to the north of the syenite. Then came the gabbro eruption and overflow and with it a crumpling of the strata and uptilting of the Animike beds. The gabbro also altered the mica schist where it lay upon it, to muscovado, destroying the schistosity and bedding and even altering the mineral constituents of the rock, heating them so that they formed new combinations, the iron and magnesia of the biotite combining to a large extent with the free quartz to make olivine, though there are some minute scales of biotite left. The same explanation of muscovado appears to answer in other places where it was seen. It seems, therefore, that the term "muscovado" is rather an ambiguous one but would be more appropriately applied to mica schist altered by gabbro than to iron-bearing Animike rock.

---

* In his report on the Lake of the Woods, Geol. of Can. CC., Mr. A. C. Lawson says that the agglomerates of that region grade into conglomerates along the strike of the formation. This has not been observed to be the case in Minnesota.

Conformable with the crystalline schists are the grauwackes, chloritic schists, diabasic schists and siliceous schists of the Keewatin series. The foregoing notes give numerous detailed facts which it was my good fortune to observe in localities particularly rich in instructive geological phenomena. These facts have a decided bearing on the nature and origin of the Keewatin group and the iron ores and associated jaspilytes which are enclosed in it.

In townships 63–9 and 64–8 immense ridges of diabase and basic agglomerates were found. These form a part of the Keewatin formation. They pass conformably into the siliceous and argillaceous schists of that series, and become themselves soft, greenish chloritic schist which retains but slight resemblance to the massive eruptive rock into which they grade and of which they are a part.

In the *American Geologist* for January, 1889, the writer gave a short resumé of the conclusions which had been reached as to the origin of these basic portions of the Keewatin. The observations which forced him to the conclusions there stated were made but a short time before; and when the article was written the fact that Mr. A. C. Lawson of the Canadian geological survey had described similar rocks in the Keewatin of the Lake of the Woods and had termed those aggregations in which the boulders are of the same material as the magma, "agglomerates" was unknown to him. Mr. Lawson also had previously offered an explanation similar to that given by the writer, of the surprising gradations observed between eruptive and fragmental rocks, viz., an alternation of "volcanic ejectamenta (both flows and tuffs) and aqueous sedimentation."

Dr. G. M. Dawson had also presented the same views and says in speaking of similar rocks in the vicinity of the Lake of the Woods, "Volcanic action would appear to offer the most reasonable explanation of their origin and distribution." *

These observations appear to parallelize our green chloritic and diabasic schists and agglomerates very closely with those of Mr. Lawson's original Keewatin. We find in them the same lenticular, basic fragments, the same "concretionary?" and associated amygdaloidal structures and the same transitions into siliceous, fragmental rocks.

It is gratifying to know that the views of these experienced geologists confirm the conclusions mentioned above. The opinion primarily held by the geologists of the Minnesota survey, with the possible exception of N. H. Winchell, and which view is still maintained by Dr. A. Winchell in the 16th Annual report, was that these rocks were of sedimentary origin and that the semi-crystalline, diabasic character was the result of intense metamorphism. The view now held is not wholly in conflict with that. It admits that portions of the Keewatin formation were purely sedimentary; but claims that the larger part of it consists of a mixture of eruptive and sedimentary materials, and is in many places extensively and wholly igneous.

In the opinion of the writer this has considerable bearing on the question of the origin of the jaspilytes embraced in the green schists of the Keewatin. They are supposed to be of some sedimentary formation which was broken up and involved in the eruptions of Keewatin age. The masses of jaspilyte are angular and have abrupt contacts with the basic schists; they are highly siliceous and are of all sizes and shapes. When the masses are large they are usually in vertical position and somewhat elongated in the direction of the schistose structure in the surrounding rock. Examples of a precisely similar disruption of a sedimentary formation and its involution in an eruptive ejection are given in the foregoing pages in referring to the masses of Huronian quartzyte and magnetite enclosed in the gabbro. In several places chalcedonic quartz similar to that in the jaspilyte of the Keewatin, was found as part of the Animike. This fact is an indication of the fragmental nature of the jaspilyte; as they cannot be separated from each other,—if one is sedimentary the other must be—and there is not much doubt that that in the Animike is.

---

* Geol. and Resources, Forty-ninth Parallel, p. 52.

The most recent fragmental formation found in northeastern Minnesota is the Huronian. Many observations were made upon a quartzyte belonging to this formation which seems to lie above the Animike slates and is the rock which contains the non-titaniferous magnetite. This quartzyte has been called Animike quartzyte: but seems to lie above the Animike proper. It is perfectly conformable with the slates and sometimes grades into rock which is feldspathic and argillaceous rather than siliceous. It was observed to lie unconformably upon the rock of the Giant's range in two or three places. The most interesting contact observed was where this rock—the semi-siliceous, feldspathic Huronian—is seen to lie unconformably upon the vertical Keewatin beds. This was announced to be the case by Dr. A. Winchell in the 16th report but no actual contacts were mentioned. Considering the greenstone upon which the Animike was found to lie west of Gunflint lake as Keewatin—which it undoubtedly is—three or more fine contacts of the Animike upon the Keewatin are reported in these notes. The significance of this fact has been pointed out before.

A peculiar transition was found south of the Giant's range, in sec. 13, 60–13, where the Animike is seen to grade downward into the syenite. The character of this transition, however, does not seem to be metamorphic, but rather fragmental. There seems to have been a certain amount of the loose, crystalline material which had resulted from the decay and erosion of the syenite lying on top of the solid rock in the bed of the sea. The

Animike sediments were deposited upon and around this syenite stuff. At first the material was mainly crystalline, the sediments forming but a very small part of the whole and only filling the cracks and cavities. A few feet farther up the materials were about evenly divided, the fine detritus filling large spaces between the elevated portions of the larger pieces of syenite. As the sediments increased and grew deeper the crystalline material was completely buried and no traces of the underlying rock were left except here and there a small fragment of syenite or an orthoclase crystal which came rolling in from above and settled down on the sediments. Sometimes these crystals are quite perfect and look strangely out of place in a rock which is so plainly sedimentary and so little altered.

As a rule there is a decided difference in the texture and appearance of the Animike and Keewatin rocks; the former having a smaller proportion of feldspathic and greenish, basic material, and usually containing more quartz and some magnetite. The slates too of the Animike are darker and appear to be carbonaceous; while the slates and schists of the Keewatin are argillaceous and hydromicaceous. These differences are so general that a person who has spent a season comparing and examining these rocks can usually tell at a glance to which formation a specimen belongs. In the vicinity of the east end of Gunflint lake, however, the Animike has a marked resemblance to the Keewatin and it is difficult to distinguish them. They both have somewhat the appearance of grauwacke and are less schistose and slaty than usual. They are of a dark gray color, have a rough surface on fresh fracture and show fewer bands of sedimentation than elsewhere. The Animike, however, contains fine grains of magnetite disseminated through it with a tendency toward a banded arrangement, and the Keewatin has none.

Although the Huronian quartzyte with which is associated the non-titaniferous magnetite lies unconformably upon the syenite of the Giant's range it is believed to lie above the Animike slates and to rest conformably upon them. The rock which was deposited at the border of the ocean upon the syenite seems to have been more siliceous than those portions of the same strata which were farther from the shore. Thus the rock which lies directly upon the syenite would be a quartzyte and would pass into the less acidic rocks farther south. This condition of things is believed to have been observed in Twp. 60–13. Still there is probably an extensive quartzyte which is later than the Animike and which lies directly upon the syenite because the land was slowly becoming more submerged and the sediments kept accumulating and extending farther and farther over the range of rock which constituted the northern limit to the ocean and the strata formed in its depths. The dip of the quartzyte corresponds with that of the slates wherever seen, and although the latter were not seen at any place underlying the former, yet their relative positions and mutual relations seem to indicate that they do so.

The gabbro has been so fully discussed in previous reports of this survey that it is necessary to say but a few words concerning it. The fact that it is found to embrace large fragments of the Huronian quartzyte and slates proves it to be of later origin. It is intersected by dykes of greenstone which are of still more recent date,—perhaps of the Cupriferous age, as that is said by the State Geologist in the Tenth annual report, p. 112, to be of more recent date than the gabbro. However, the appearance of these rocks in sec. 35, 58–6 gave me the impression that the gabbro is on top of the Cupriferous and hence more recent.

A coarse basaltic structure was seen in the gabbro on the south side of Tucker lake. There was also an appearance of sedimentary structure in the gabbro in N. W. ¼ sec. 2, 64–3, caused by parallel bands of magnetite several feet in length. It shows how one may be deceived by similar banded structure in other places.

Coarse hornblende, believed to be the largest ever found in this state, was found in the gabbro in the S. E. ¼ sec. 25, 63–10. Crystals six inches long were obtained. Many seen in the same place were even larger.

LIST OF SPECIMENS COLLECTED BY H. V. WINCHELL DURING THE SUMMER OF 1888.

354. Hydrated hematite. John Mallmann's working. Sec. 29, 59–14.

354 A. Gray, feldspathic rock, to which is attached a pebble(?) of hematite. Same locality.

355. Gray rock containing magnetite. Short distance west of last.

355 A. Gray rock containing limonite. From main shaft at same place.

356. Magnetitic chrysolyte. 400 paces east of the W. ¼ post sec. 10, 60–12.

357. Syenite. S. W. ¼ sec. 8, 60–12.

358. Olivinitic magnetite. One-fourth mile south of N. W. corner sec. 17, 60–12.

359. Greenish, magnetitic, olivinitic quartzyte. S. W. ¼, S. W. ¼ sec. 17, 60–12.

360. Dark, siliceous magnetite. N. E. corner sec. 19, 60–12.

361. Slaty, carbonaceous rock. Same locality.

362. Stratified magnetite and quartzyte or siliceous schist. N. W. ¼, N. E. ¼ sec. 19, 60–12.

363. Magnetite. N. W. ¼, N. E. ¼ sec. 19, 60–12.

364. Quartz conglomerate with a green matrix. From boulders seen east of Iron lake. N. W. ¼ sec. 24, 60–13.

365. Hornblendic Animike slate. A short distance north of last locality.

366. Samples showing the transition from Animike to the syenite of the Giant's range. North end of Iron lake, S. W. ¼ sec. 13, 60–13.

367. Greenish Animike rock containing a felsitic boulder. Same locality.

368. Coarse, micaceous syenite, N. E. ¼ sec. 14, 60–13.

369. Black, magnetitic rock, S. W. side of Iron lake. N. E. ¼ sec. 23, 60–13.

370. Tough, dark magnetitic rock. N. W. ¼ sec. 35, 60–13.

371. Reddish-gray quartzyte. Found in fragments on the trail in N. W. ¼ sec. 32, 60–13.

372. Samples from the bottom of the Animike where it passes into and rests upon the syenite. South of the trail. S. W. ¼, N. W. ¼ sec. 32, 60–13.

373. Black, carbonaceous slate rock containing magnetite. S. W. ¼, S. W. ¼ sec. 32, 60–13. From a shaft.

374. Grayish rock containing bands of magnetite. A little N. W. of last.

374 A. Reddish, jaspery rock. Same locality.

375. Weathered samples of magnetitic rock. S. W. ¼ sec. 31, 60–13.

376. Sample of reddish, decomposed jaspery rock from top of a shaft in N. E. ¼ sec. 11, 59–14.

376 A. Hematitic rock from bottom of the same shaft.

377. Feldspathic Keewatin schists. N. W. ¼ sec. 11, 59–14.

378. Feldspathic, gray, Keewatin schist, S. E. "forty" sec. 11, 59-14.

379. Olivinitic, magnetitic rock. From a shaft in N. W. ¼ sec. 14, 59–14.

380. Dark, slaty rock containing needle-shaped crystals of hornblende and bands of black jasper. Sec. 22, 59–14.

381. Grayish, soft, sericitic schist, S. E. ¼ sec. 17, 59–14.

382. Gray syenite of the Giant's range, Hinsdale.

382 A. Red syenite containing decayed hornblende. Found near seams or faults in the syenite at Hinsdale.

383. Hornblende schist from included boulder-forms in the syenite, Hinsdale.

384. Fine, gray granite, found cutting the syenite at Hinsdale.

385. Dark, red, decomposed syenite. Three miles north of the Giant's range on the railroad.

386. Gabbro. Sec. 5, 58–14. In a railroad cut three-fourths of a mile north of Beaver creek.

387. Dark, silico-argillaceous rock apparently carbonaceous. N. E. ¼, S. W. ¼ sec. 9, 58–14. On Partridge river.

388. Reddish, hematitic, quartzose rock. From a shaft in N. E. ¼, S. E. ¼ sec. 11, 59–14.

389. Feldspathic Keewatin schist. Near the centre of S. E. ¼ sec. 11, 59–14.

389 A. Quartz from veins in last. Containing talc.

390. Dark, carbonaceous (?) rock supposed to be Keewatin. Same locality.

391. Felsitic siliceous schist. N. E. ¼ sec. 15, 59–14.

392. Magnetic, olivinitic iron ore, about 200 paces southeast from last and 40 feet higher.

393. Magnetic iron ore. N. W. ¼, N. W. ¼ sec. 14, 59–14.

394. Pinkish quartzyte. Found in angular fragments on the trail in Twp. 60-13.

395. Black magnetic sand. Birch lake, S. W. ¼, S. E. ¼ sec. 32, 61–12.

396. Fine, muscovado-like gabbro. N. E. ¼ sec. 26, 61–12.

396 A. Specimen of a boulder (?) enclosed in last.

397. Animike or Huronian quartzyte. S. E. ¼, N. E. ¼ sec. 26, 61–12.

397 A. Hornblendic quartzyte. Same locality as last.

397 B. Quartzyte containing unknown mineral. Same place.

397 C. Magnetitic quartzyte. Same locality.

398. Stratified quartzyte and magnetite. S. E. ¼ sec. 26, 61–12.

399. Olivinitic quartzyte. E. ½, N. W. ¼ sec. 35, 61–12.

399 A. Coarse quartzyte and magnetite. Same locality.

400. Syenite, pink and rather coarse. S. E. ¼, N. E. ¼ sec. 35, 61–12.

401. Quartzyte, containing much magnetite. Same locality.

402. Hornblendic, olivinitic magnetite rock. N. E. ¼, S. W. ¼ sec. 35, 61–12.

403. Coarse quartzyte and fine chrysolyte. S. W. "forty," sec. 35, 61–12.

404. Chrysolyte. S. W. ¼ sec. 35, 61–12.

405. Olivine bearing magnetitic quartzyte. N. ½, S. E. ¼ sec. 24, 61–12.

405 A. Hornblendic samples of last.

405 B. "Slickensides." Same locality.

406. Hard, hornblendic Animike found lying upon syenite. S. E. ¼, N. E. ¼ sec. 35, 61–12.

407. Magnetite and quartzyte in banded alternation. S. E. ¼ sec. 30, 62–10.

408. Granular olivinitic rock. Same locality.

409. Fine grained olivinitic magnetite. Same locality.

410. Titaniferous (?) magnetite. Same locality.

411. Hornblendic olivinitic quartzyte. Same locality.

412. Coarse gabbro. S. E. ¼, N. E. ¼, sec. 36, 63–10.

412 A. Coarse hornblende and labradorite. Same locality.

413. Altered Animike from fragments enclosed in the gabbro. Same locality as 412.

414. Coarse magnetite. Same place.

415. Very coarse hornblende. From the gabbro. S. E. ¼, S. E. ¼ sec. 25, 63–10.

416 and 416 A to 416 E represent a transition from sericitic schist to granite.

417. Micaceous hornblendic schist. Same locality.

418. Biotitic hornblendic schist. N. W. forty sec. 4, 63–12.

419. Calciferous sericite schist. N. W ¼ sec. 4, 62–12.

420. Gabbro from lake Isabelle. N. W. ¼, S. E. ¼ sec. 35, 62–8.

420 A. Gray, fine granular rock contained in last.

421. Pebbles from a point just east of last.

422. Dyke rock. S. W. ¼, S. E. ¼ sec. 36, 62–8.

423. Fine, brown gabbro containing biotite. East of lake

Isabelle in T. 62–7.

424. Gray labradorite rock. Two miles up Swamp-lake river from lake Isabelle.

424 A. Gray gabbro with a streak of red in it. Same place.

424 B. Red gabbro. Same locality as last two.

425.
425 A.
425 B.
425 C.
Specimens illustrating a change from gabbro to dark, tough hornblendic rock.

426. Hornblendic gabbro. East of the north end of lake Harriet.

427. Gabbro. From a small island near the south end of Nine Mile lake.

428. Gabbro. From west side of Crooked lake.

429. Trap rock. Sec. 15, 59–6. West of the narrows.

430. Fine grained, olivinitic gabbro. West side of Nine Mile lake.

431. Gabbro. Sec. 35, 58–6.

432. Red, impure felsyte. East of last a few rods.

433. Siliceous Keewatin schist. About 40 rods up the creek which enters the east end of Gunflint lake from the northeast.

434. Sericitic schist. Farther up the creek on east side.

435. Reddish, jaspery Animike rock. Bed of same creek.

436. Dark, ferruginous conglomerate. About one-fourth mile up the creek.

437. Greenish, sericitic schist. East of last a few rods.

438. Animike from near a contact with Keewatin. Bed of same creek.

439. Keewatin rock from same place.

440. Magnetitic gabbro. N. E. ¼, N. W. ¼ sec. 2, 64–3.

441. Dioritic. magnetitic gabbro. S. W. ¼, N. W. ¼ sec. 2, 64–3.

442. Titaniferous magnetite. S. E. ¼, N. W. ¼ sec. 2, 64–3.

443. Black carbonaceous slate. N. W. ¼ sec. 35, 65–3.

444. Greenstone. Found lying on top of 443 (H).

445. Porphyry or porphyrel. Loose mass at same place.

445 A. Trap found stuck fast to 445.

446. Very strongly magnetic iron ore. N. W. ¼, N. W. ¼ sec. 23, 65–4.

447 and 447 A to 447 E illustrate a transition from Black Animike slate to greenstone. N. E. ¼ sec. 25, 65–4.

447 F. Porphyritic trap rock. Same locality.

398. Stratified quartzyte and ma
61–12. on sec. 28,
399. Olivinitic quartzyte. E. ½.
399 A. Coarse quartzyte and n
400. Syenite, pink and rathe
35, 61–12.
401. Quartzyte, containing m at same
402. Hornblendic, oliviniti
¼ sec. 35, 61–12. of the
403. Coarse quartzyte an
sec. 35, 61–12. 35, 65–5.
404. Chrysolyte. S. W. underlying green-
405. Olivine bearing m
24, 61–12.
405 A. Hornblendic s act 150 paces west
405 B. "Slickensid of the greenstone from
406. Hard, hornbl receding from the line of
S. E. ¼, N. E. ¼ sec.
407. Magnetite a
sec. 30, 62–10. from the western contact.
408. Granular 250 paces east of last.
409. Fine grai ish brown rock composed of plagi-
410. Titanife magnetite. North of last in a high
411. Hornb
412. Coars blendic gabbro. S. line sec. 12, 64–6.
412 A. Co michigama lake. N. E. ¼ sec. 6, 64–5.
413. Alte imike. South side of the island in N. W. ¼
bro. Same
414. Co itic gabbro. S. E. ¼ sec. 1, 64–6.
415. posed gray quartzyte. Under the gabbro at same
E. ¼ sec.
416 a onglomeritic grauwacke. N. W. ¼ sec. 33, 66–6. South
schist Track lake.
417. Rock resembling magma of Ogishke conglomerate.
41 locality.
4 464 A and 464 B illustrate the passage of grauwacke into

6 465. Magnetitic siliceous schist. N.W. ¼, N. W. ¼ sec. 33, 66–6.
466. Magnetitic jaspery rock. On hill east of last.
466 A. Contact specimen between 466 and siliceous greenish Keewatin schist. Same locality.
467. Amygdaloidal calciferous rock from boulders enclosed in

loritic schist. North side of Otter Track lake. N. W. ¼
6, as in Minn.

rom similar boulders not amygdaloidal. Same

eous breccia found immediately surrounding the

yte. Short distance east of last.

agnetite. Same locality.

n schist from near a contact with 469.

A. Jasper from same contact.

Feldspathic, semi-crystalline schist. From the corner
d "R 333" and "R 337" about half a mile north of Otter
k lake.

472. Coarsely porphyritic green rock. North side of a lake which lies on the north side of Otter Track lake.

473 and 473 A. Keewatin rock turning into red and black jasper. North of Otter Track lake.

473 B. Magnetite in green schist. Same locality.

474. Jasper and magnetite. Same locality.

475. Average sample of the non-schistose Keewatin from north of Otter Track lake.

476. Argillyte. N. W. ¼, S. E. ¼ sec. 2, 64–8. Lake Vira.

477. Fine mica schist. S. W. ¼, S. W. ¼ sec. 32, 64–8. Between Snowbank and Disappointment lakes.

478. Red, fine syenite. Cutting last.

479. Mica schist. S. E. ¼ Sec. 32, 64–8.

480. Conglomeritic mica schist. Same locality.

480. A. Red granite from intrusions in 480.

481. Trap rock from a dyke cutting 480.

482. Mica schist. S. E. ¼, N. E. ¼ sec. 6, 63–8. Round lake.

483. Syenite gneiss. N. W. ¼, N. E. ¼ sec. 6, 63–8. Round lake.

484. Dark siliceous syenite. West side of Round lake.

485. Micaceous syenite. N. W. ¼, N. E. ¼ sec. 7, 63–8. Round lake.

486. Gabbro. Found lying on 485.

487. Hardened mica schist. S. E. ¼ sec. 6, 63–8.

488. Fine red syenite. Intrusion in last.

489. Finely conglomeritic mica schist. N. E. ¼ sec. 5, 63–8. Disappointment lake.

490, 490 A and 490 B represent a transition from mica schist to muscovado. N. E. ¼, S. W. ¼ sec. 4, 63–8.

447 G. Dyke rock. Same locality.

448. Brecciated Animike slate. Same locality.

449. Quartz conglomerate not seen in place. From sec. 28, 65–4.

450. Magnetite. N. W. ¼ sec. 28, 65–4.

451. Biotitic altered greenstone. Same locality.

452. Diamond drill cores. Same locality.

452 A. Pyritous quartzyte from bottom of Animike at same place.

453. Drillings from about one-eighth mile south of the "camp" in sec. 28, in 65–4.

454. Quartzyte and magnetite. N. W. ¼ sec. 35, 65–5.

455. Animike from next to a contact with underlying greenstone. N. W. ¼ sec. 35, 65–5.

455 A. Animike rock from a similar contact 150 paces west of last.

456 and 456 A to 456 C are samples of the greenstone from the eastern contact taken in order receding from the line of contact.

456 D is a sample of greenstone from the western contact.

457. Conglomerate greenstone. 250 paces east of last.

458. Fine, crystalline, grayish-brown rock composed of plagioclase, mica, olivine and magnetite. North of last in a high ridge.

458. A. Coarse, hornblendic gabbro. S. line sec. 12, 64–6.

459. Gabbro. Gabemichigama lake. N. E. ¼ sec. 6, 64–5.

460. Modified Animike. South side of the island in N. W. ¼ sec. 6, 64–5.

461. Magnetitic gabbro. S. E. ¼ sec. 1, 64–6.

462. Decomposed gray quartzyte. Under the gabbro at same locality.

463. Conglomeritic grauwacke. N. W. ¼ sec. 33, 66–6. South of Otter Track lake.

463 A. Rock resembling magma of Ogishke conglomerate. Same locality.

464, 464 A and 464 B illustrate the passage of grauwacke into flint.

465. Magnetitic siliceous schist. N.W. ¼,N. W. ¼ sec. 33, 66–6.

466. Magnetitic jaspery rock. On hill east of last.

466 A. Contact specimen between 466 and siliceous greenish Keewatin schist. Same locality.

467. Amygdaloidal calciferous rock from boulders enclosed in

green chloritic schist. North side of Otter Track lake. N. W. ¼ sec. 27, 66–6, as in Minn.

467. A. From similar boulders not amygdaloidal. Same place.

468. Calciferous breccia found immediately surrounding the boulder forms.

469. Jaspilyte. Short distance east of last.

469. A. Magnetite. Same locality.

470. Green schist from near a contact with 469.

470. A. Jasper from same contact.

471. Feldspathic, semi-crystalline schist. From the corner marked "R 333" and "R 337" about half a mile north of Otter Track lake.

472. Coarsely porphyritic green rock. North side of a lake which lies on the north side of Otter Track lake.

473 and 473 A. Keewatin rock turning into red and black jasper. North of Otter Track lake.

473 B. Magnetite in green schist. Same locality.

474. Jasper and magnetite. Same locality.

475. Average sample of the non-schistose Keewatin from north of Otter Track lake.

476. Argillyte. N. W. ¼, S. E. ¼ sec. 2, 64–8. Lake Vira.

477. Fine mica schist. S. W. ¼, S. W. ¼ sec. 32, 64–8. Between Snowbank and Disappointment lakes.

478. Red, fine syenite. Cutting last.

479. Mica schist. S. E. ¼ Sec. 32, 64–8.

480. Conglomeritic mica schist. Same locality.

480. A. Red granite from intrusions in 480.

481. Trap rock from a dyke cutting 480.

482. Mica schist. S. E. ¼, N. E. ¼ sec. 6, 63–8. Round lake.

483. Syenite gneiss. N. W. ¼, N. E. ¼ sec. 6, 63–8. Round lake.

484. Dark siliceous syenite. West side of Round lake.

485. Micaceous syenite. N. W. ¼, N. E. ¼ sec. 7, 63–8. Round lake.

486. Gabbro. Found lying on 485.

487. Hardened mica schist. S. E. ¼ sec. 6, 63–8.

488. Fine red syenite. Intrusion in last.

489. Finely conglomeritic mica schist. N. E. ¼ sec. 5, 63–8. Disappointment lake.

490, 490 A and 490 B represent a transition from mica schist to muscovado. N. E. ¼, S. W. ¼ sec. 4, 63–8.

490 C. Mottled muscovado. Same locality.

491. Olivinitic magnetite and quartzyte. Same place.

492. Fine gabbro found lying upon 491.

493. Coarse labradorite gabbro. South of last.

493 A. Titaniferous (?) magnetite. Found in last.

494. Feldspathic, muscovado-like mica schist. N. E. ¼ sec. 4, 63–8.

495. Fine, micaceous syenite. S. W. ¼ sec. 34, 64–8.

496. Conglomeritic mica schist. N. E. ¼ sec. 33, 64–8.

497. Diabasic conglomerate. From N. W. ¼ sec. 34 and S. W. ¼ sec. 27, 64–8.

498. Diabasic schist. Same locality.

499. Diabase. Same locality.

500. Gneissic schist from lake shore having a foliation from N. W. to S. E., N. W. ¼ sec. 34, 64–8.

501. Biotitic trap. S. W. ¼ sec. 27, 64–8.

502. Siliceous greenstone. N. E. ¼, S. W. ¼ sec. 27, 64–8.

503. Porphyritic mica schist conglomerate. S. W. ¼, N. W. ¼ sec. 27, 64–8.

504. Conglomeritic mica schist. S. W. ¼ sec. 11, 63–9.

505. Muscovado. North of quarter post between sections 14 and 15, 63–9.

505 A. Titaniferous (?) magnetite. Same locality.

506. Fine, gray, hornblendic mica schist. S. W. ¼, N. W. ¼ sec. 16, 63–9.

507. Diabase, 340 paces north of W. quarter post sec. 16, 63–9.

508. Diabase. N. W. corner sec. 16, 63–9.

509. Fine conglomeritic diabase. 375 paces north of the S. W. corner sec. 9, 63–9.

510. Porphyrelle. N. E. ¼ sec. 8, 63–9.

510 A. Porphyrelle containing red jasper. Same locality.

510 B. Porphyrelle containing greenstone. Same locality.

511. Diabasic rock found enclosing jaspilyte. N. E. ¼ sec. 8, 63–9.

511 A. Contact specimens of diabase and jaspilyte. Same locality.

511 B. Diabase containing fragments of jaspilyte. Same locality.

511 C. Porphyritic diabase containing fragments of porphyrelle. Same locality.

512. Soft talcose rock. Same general locality.

513. Gray schistose rock found in contact with jaspilyte. Same locality.

514. Jaspilyte (jasper and magnetite). Same locality.

515. Porphyrelle. N. W. ¼, N. E. ¼ sec. 8, 63-9.

516. Trap rock. Cutting last.

517. Rotted diabase. Southwest of last some distance.

518. Micaceous diabasic schist. Same general locality.

519. White, crumbling jasper. Sec. 8, 63-9.

520. Dark, ancient conglomerate in contact with the porphyrelloid conglomerate. Sec. 8, 63-9.

521. Contact specimen. Diabase and porphyrelle. Sec. 8, 63-9.

522. Coarser diabase than usual, having white crystals of feldspar on weathered surfaces.

522 A. Fine diabase cutting 522.

523. Fine grained olivinitic mica schist. S. W. forty sec. 10, 63-9.

523 A. Conglomeritic mica schist. Same locality.

523 B. Diabasic mica schist. North of last.

524. Rusty, decomposed mica schist. Same locality.

525. Mica schist showing stratification. At 300 paces north of the S. W. corner sec. 10, 63-9.

526. Mica schist from a contact between it and diabase. 100 paces north of last.

527. Diabase from same contact.

528. Diabase. N. W. ¼, S. W. ¼ sec. 10, 63-9.

529. Dark, pitted mica schist. Same locality.

530. Diabasic strata in mica schist. Same locality.

531. Porphyritic mica schist. North of last.

532. Diabase conglomerate. Same general locality.

533. Mica schist, somewhat diabasic. Just south of the quarter post between secs. 3 and 4, 63-9.

534. Porphyrelle. N. E. corner sec. 4, 63-9.

535. Argillitic mica schist. Same locality.

536. Porphyrelloid conglomerate. S. E. ¼, N. W. ¼ sec. 4, 63-9.

537. Jaspilyte. S. W. ¼, N. W. ¼ sec. 4, 63-9.

538. Diabase from contact with Jaspilyte. Same locality as last.

538 A and 538 B are from a distance of five and ten feet respectively from this contact.

538 C. A phase of the diabase which does not look so basic. Same place.

539. Black jasper and magnetite. Same locality.

Nos. 540 and 540 A to 540 J illustrate a transition from fine diabasic schist through siliceous argillyte to porphyrelle which takes place between the N. W. corner sec. 4 and the E. quarter post sec. 8, 63-9.

541. Mica schist. N. W. ¼, N. W. ¼ sec. 9, 63-9.

542. Fine, dark syenite. N. W. ¼, N. E. ¼ sec. 9, 63-9.

ELEVATIONS DETERMINED BY ANEROID BAROMETER BY H. V. WINCHELL.

	Ft. above L. Superior.
Devil's Track river at the crossing of the county road north of Grand Marais	1000
Top of "Pine Mountain," 12 miles from the lake	1550
South Brulé river at the crossing of county road	1000
Birch lake, Twp. 65-2	1220
Duncan's lake	1205
Rose or Mud lake	1060
South lake	1085
North lake	1085
Gunflint lake	1080
Loon lake	1275
Mayhew lake	1385

Lake Vira is about the same hight as Knife lake.
Ensign lake is 40 feet lower than Knife lake.
Snowbank lake is 45 feet higher than Knife lake.
Disappointment lake is 120 ft. higher than Knife lake.
Round lake is 90 feet higher than Knife lake.
Kawishiwi river is 57 feet higher than Knife lake where the portage from Snowbank lake strikes it. N. W. ¼ sec. 15, 63-9.

CONTACTS OBSERVED.

Animike on the syenite of the Giant's range, north of Iron lake; also west of Gunflint lake, N. W. ¼ sec. 23, 65-4; also S. E. ¼, N. E. ¼ sec. 35, 61-12.

Gabbro on Animike, N. E. ¼ sec. 26, 61-12 south of Birch lake; also south side of Disappointment lake. Gabbro on syenite, N. W. ¼ sec. 24, 61-12; also N. E. ¼ sec. 7, 63-8. Fine-grained gabbro or trap on Animike slate, east end of Gunflint lake, and around Loon lake. Animike on Keewatin, creek bed at east end of Gunflint lake; also N. W. ¼ sec. 35, 65-5; also N. E. sec. 25, 65-4.

Trap rock on porphyrel, Loon lake; also sec. 8, 63–9. Jaspilyte and porphyrel, Twp. 63–9, many places. Jaspilyte and diabase, many places in Twp. 63–9. Mica schist and diabase, S. W. ¼ sec. 10, 63–9. Mica schist and porphyrel, N. E. corner sec. 4, 63–9.

TRANSITIONS OBSERVED.

From Animike to syenite. North of Iron lake.

From Keewatin hydromica schist to granite. N. E. ¼ sec. 9, 63–12.

From black Animike slate upward to fine gabbro or trap. South side of Loon lake.

From black Animike slate downward to trap. N. E. ¼ sec. 25, 65–4.

From mica schist to "muscovado" and back to mica schist. N. E. ¼ sec. 4, 63–8.

From mica schist to diabase. N. W. ¼ sec. 34, 64–8.

From diabase through diabasic agglomerate to chloritic schist. Twp. 63–9.

From diabasic schist through siliceous schist to porphyrel. Twp. 63–9.

CONGLOMERITIC STRUCTURE OBSERVED IN

Keewatin, in schistose, porphyrelloid and diabasic portions.

Animike, in various places.

Syenite of Giant's range, at Hinsdale.

Mica schist and porphyrelloid mica schist. S. E. ¼ sec. 32, 64–8.

Gabbro, containing fragments of Animike. N. E. ¼ sec. 26, 61–12.

REPORT OF ULY. S. GRANT.

IV.

REPORT OF GEOLOGICAL OBSERVATIONS MADE IN NORTHEASTERN MINNESOTA DURING THE SUMMER OF 1888.

By Uly. S. Grant.

I. General Statement.

During the latter part of June, all of July, and the greater part of August a party was employed in collecting sets, of twenty-five specimens each, of the typical rocks of northeastern Minnesota. Besides the writer, the party consisted of Mr. A. D. Meeds, of the University, and two Indians, Charley and Nick Sucker, from Vermilion lake. The traveling was done entirely by canoe, as is usual in this region. The town of Ely, which is now the northern terminus of the Duluth and Iron Range railroad, was used as a supply point, and from here three trips were made eastward and south-eastward,—each trip taking about three weeks. Most of the country from Vermilion lake east to Gunflint lake, explored by the survey during the last two summers, was passed over, and rock samples collected from various localities designated by Prof. N. H. Winchell. The samples are of museum size—three by four inches—and bear the numbers given by Prof. Winchell in the tenth, fifteenth and sixteenth annual reports of the survey. In all forty-five sets, or over eleven hundred specimens, were collected; these, together with those collected in 1886 and 1887, form quite a complete series of typical rocks of that part of the state lying north of lake Superior. The specimens were shipped to Minneapolis and are now in the rooms of the survey,—but as yet they have not been unpacked and labeled.

While collecting the rock samples some attention was paid to the geology; thus a few additional facts were noted, and several places, not before visited by the survey, were examined. But these observations were not very extensive, as the time was limited and the main object was to collect the samples wanted. This fact, together with the inexperience of the writer in the line of geology, will perhaps account for discrepancies in the following pages. The only place where any detailed observations were made was on the north shore of Gunflint lake while trying to discover the western extension of the belt of hornblende schists (Vermilion series) which lie between the vertical earthy schists (Kewatin) on the south and the gneiss on the north.

During the latter part of August, all of September and the first half of October the writer was engaged, under the direction of Mr. H. V. Winchell, in examining reported outcrops of iron ore. While thus employed, two separate trips were made,—one from Gunflint lake south to Brulé lake, and one along the Kawishiwi river in T. 63-7 and 62-9. A few notes, concerning the general geology of the country thus passed over, are given; but it should be remembered that the main object of these trips was to examine into the richness and extent of the iron ore outcrops. Notes on a few of the lakes passed through on a trip from Kawishiwi lake south to lake Superior are also given; but a full account of this trip will be found in the report of Mr. H. V. Winchell.

Owing to the numerous heavy spring rains, all the lakes and rivers were very high,—from two to five feet higher than during the summers of 1886 and 1887; this rendered examination of rock exposures along the lake shores more difficult than formerly, as in many cases the water extended back over the rocky shores to the soil. The insect pests (black-flies and mosquitoes) were also very numerous and troublesome.

The Canadian side of the boundary lakes and rivers from Gunflint lake to Ottertrack lake, seems to have been surveyed during the last year.

The rock samples, which illustrate the following notes, are numbered from 1 up to 298, the letter G being placed on each specimen, after the number. The figures are green,—paris green and shellac dissolved in alcohol being used.

The township, section and quarter section, where each specimen was found, is given. The township (in this report) is always north and the range west of the fourth principal meridian, Minnesota.

Appended to this report will be found (1) a brief summary of observations, (2) a list, with notes, of the typical rocks of which 25 specimens were collected, (3) a table of barometric elevations and (4) a catalogue of rock samples to illustrate the writer's notes.

Magnetic bearings were taken roughly in the field; these have not been corrected either for general or local variations.

II. GEOLOGICAL NOTES.

OTTERTRACK LAKE.

This is one of the boundary lakes, and extends north-east and south-west in T. 66–6. On the north shore of the lake in N. E. ¼ of N. W. ¼ sec. 27, T. 66–6 (if the Minnesota sections were extended northward to the Canadian shore) is a cliff about forty feet high; this cliff is composed of magnetic iron slates banded with red and black; the red bands are jasper and the black ones are composed mostly of magnetite. The banding is twisted and bent in every direction, but is almost always in a vertical plane. Mr. J. F. Conniff of Duluth tells me that on the south side of the lake in the N. ½ of sec. 33 (80 rods south of the lake shore), there is an exposure of these vertical iron slates; he says they appear in the form of a "vein," from four to twelve feet wide, and strike east and west. No. 1 and No. 2 are specimens he gave me from this locality; No. 3 is from the cliff on the north shore of the lake. The first outcrop on the shore west of these slates is represented by No. 4, and the first east of them by No. 5, both of which are graywacke-like rocks. A full account of this place will be found in the report of Mr. H. V. Winchell; also see the sixteenth annual report, p. 210, for the geology of Ottertrack lake.

GUNFLINT LAKE AND VICINITY.

This lake lies on the boundary in the north part of T. 65–3, and extends eastward into T. 65–2; it also touches the eastern side of T. 65–4.

On the small island in S. E. ¼ of S. E. ¼ sec. 13, T. 65–4, were found five elongated pieces of a dark schist, which is composed principally of hornblende and feldspar, the latter weathering pinkish; these pieces are in the syenite of which the island is composed; the largest piece was five feet long and seven inches wide; the long axis of each piece extends in the same direction, —i. e. N. 85° W. (Mag.). All the pieces, except one, thin out into wedge-shaped ends. No. 6 represents the syenite, and No. 7 the schist. The largest of these pieces is shown in Fig. 1.

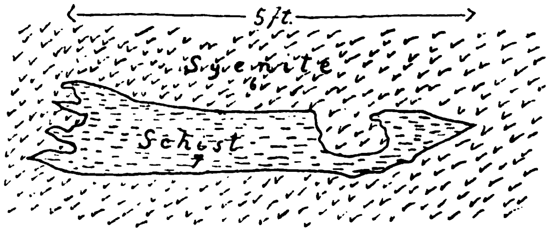


Fig. 1. Hornblende schist inclosed in syenite, Gunflint lake.

Sections north of Gunflint lake. Three sections were made north from the lake near the centre of the northern shore, the object being to discover what becomes of the hornblende schist belt (the Vermilion series of the survey) that was found north of the lake near its eastern end in 1887. If this belt continues in the same strike as there seen, it should appear again in Blackfly bay north of the narrows of the lake; but no trace of it is here found. The measurements in these sections are only roughly estimated, the ground being too rough and too much covered with underbrush to allow pacing. The location of the observations is given as accurately as possible, supposing the section lines of the Minnesota townships to be extended to the Canadian side. Fig. 2 shows the relations of this belt of crystalline schists and of the Kewatin slates to the syenitic gneiss. For the description of this belt of hornblende schists the reader is referred to the sixteenth annual report, pages 68–77, 262–6, 337, and the map on page 255.

SECTION I: North from the lake shore a little west of the line between secs. 14 and 15, T. 65–3. This would be directly north of the east end of the island in sec. 15—the only island in this part of the lake.

The first rock exposed is a vertical sericitic schist, on the lake shore; it extends east and west about 200 yards; this is the most westerly, but one, exposure of vertical schists on Gunflint lake. This rock is represented by No. 11; the exposure continues north 100 feet, and rises 8 feet above the water. After passing a swamp 250 feet wide, a hill rises 60 feet above the lake; this hill is composed of schist or slate similar to No. 11, but it is growing harder and more flinty (No. 12); this hill is 200 feet across. Beyond is another swamp about 200 feet wide, and then rises a second ridge, 400 feet in width; the first exposure is of a fine porphyrelloid rock (No. 13) with small crystals of white feldspar; these crystals are arranged more or less in layers corresponding to the strike. The rest of the hill is composed of alternating beds of black slate (No. 16) and porphyrelloid rock represented by No. 13; the latter rock varies from that in which the feldspar crystals are quite conspicuous, ⅛ inch or more in diameter (No. 14), to that in which they are quite small (No. 15). Near the top of the hill and lying in a small depression is a mass of dark trap (No. 17); the contact between the trap and slate was covered by soil. Nearer still to the top of the hill are two dikes, one and four feet in width; these dikes run parallel with the beds of slate and are exposed for over 20 feet; in the larger are fragments of baked slate; and the outer portion of this dike is very much finer-grained (No. 18) than the inner (No. 19); Nos. 18 and 19 seem to be about the same as No. 17. On the summit of the hill in the porphyrelloid schist is an elongated mass of a soft schistose rock (No. 20) running N. 70° W. (Mag.), diagonally across the bedding; this rock was traced ten feet before disappearing under the soil; the schist is in no wise changed near the contact, and near by it is bent around some smaller lenticular masses of the same rock (No. 20).

Going north for the next half mile the following country is passed over:—

Swamp;—no exposures.

Ridge, about 200 feet above the lake, composed of black slate and fine porphyrelloid schist. On the north side of this hill gabbro, similar to that on the lake shore, was found.

Rock covered.

Very hard black slate (No. 21), containing specks of iron pyrites; also porphyrelloid schist.

Rock covered.

Black slate.

Gabbro; contact with slate not seen.

Rock covered.

Gabbro represented by No. 22.

Rock covered for 50 feet.

Black slate, No. 23; strike N. 85° E. (Mag.).

Rock covered for about 150 yards, and ground rapidly descending toward the north.

At the foot of the descent was a rather coarse porphyrelloid schist (No. 24) largely composed of a soft mineral, probably sericite.

Now comes a rather level, almost swampy, place with a few small hills; it extends for about a third of a mile, as follows:—

Rock covered; swamp, about 1,000 feet.

Black slate.

Rock covered.

Micaceous schist (No. 25); this is probably in place.

Rocks covered for about 300 feet.

One hundred feet of a heavy black hornblende schist; vertical, strike N.85° E. (Mag.). At the south side of this exposure the rock is represented by No. 26; this seems to be composed of hornblende with some feldspar; the schistose structure is very pronounced. This rock soon grades into No. 27, which is heavier and has better developed hornblende crystals; the schistose structure is not very evident, except on the weathered surfaces.

The rock was now covered for about 200 feet, and then came an exposure of a very hard, dark, fine-grained mica-schist (No. 28.). This exposure was 20 feet wide (N. and S.) and 40 feet long; strike E. and W. (Mag.); vertical.

After another swamp, 400 feet wide, came an exposure, 50 feet wide, of vertical schist; this consisted of parallel bands of several kinds represented by Nos. 29, 30, 31 and 32. No. 29 is light colored, composed mostly of feldspar, which weathers pinkish, and a small amount of mica; bands of this were of all widths up to one foot; this rock made up about one-half of the exposure. No. 30 is darker and contains much hornblende. No. 31 contains still more hornblende; bands of this and the preceding were not over six inches wide. No. 32 is a very dark, fine, mica-schist; no bands of this over two and a half inches in width were seen. Samples could be found all the way between No. 29 and No. 32, but the outlines of the different bands were very distinct. The bands would often run out to needle-points and disappear.

Beyond another swamp, about 400 feet wide, was a small hill, covered by soil, but on removing the thin layer of soil the solid rock was exposed; this rock (No. 33) is composed of hornblende and feldspar; it is quite firm and on fresh surfaces appears rather massive, but on the weathered surfaces the schistose structure is plainly seen; this schistosity is vertical and strikes N. 85° E. (Mag.). The rock contained a few small areas in which the hornblende seemed to be collected in great quantity.

Beyond the last exposure was a swamp extending northward; no hills could be seen for three-fourths of a mile.

Taking the sum of the foregoing distances, roughly estimated, we have a section, straight across the strike of the slates and schists, of 6,790 feet, or somewhat over a mile and a quarter. This would give the belt of earthy schists and slates (Kewatin) a width of 4,810 feet; and the crystalline schist belt (hornblende and mica-schists), extending north from No. 26 (No. 25 not being included, as it was not positively determined to be in place), would have a width of 1,220 feet. The width of the latter belt is probably greater than 1,220 feet, as the northern limit may not have been reached and there are 670 feet between the slates and the southern outcrop of crystalline schists where no exposures were seen.

SECTION II: This section runs directly north from the lake, and is about three-fourths of a mile west of section I, or very near the line between secs. 15 and 16, if this line were extended northward from the Minnesota side. For the first half mile from the lake there is a well-cut surveyor's line.

At the lake shore there are Animike slate fragments, and just beyond this and 15 feet above the water is a ridge of gabbro, which is about 200 feet across. A swamp extends for one-half mile from the shore; beyond this swamp is about 700 feet of dry, level ground with no rock exposures. Then comes a low ridge, 50 feet across, on which are many granite boulders and a few gabbro fragments, but no rock was seen in place. After crossing 500 feet of lower ground we came to a small ridge of gneiss (No. 34) composed of quartz and feldspar, with some hornblende and a small quantity of a light-yellow mineral.

After passing over two other small ridges of gneiss there comes a range of large hills of the same gneiss; from the first appearance of this rock to the range of large hills is about 600 feet. The gneissic structure can be plainly seen on the weathered surfaces; it is vertical and runs about E. and W. (Mag.). This range is from 40 to 75 feet above the swamp, and extends eastwardly,—the southern front being precipitous and running N. 55° E. (Mag.); south of it is a valley surrounded by hills; the location is shown in Fig. 2.

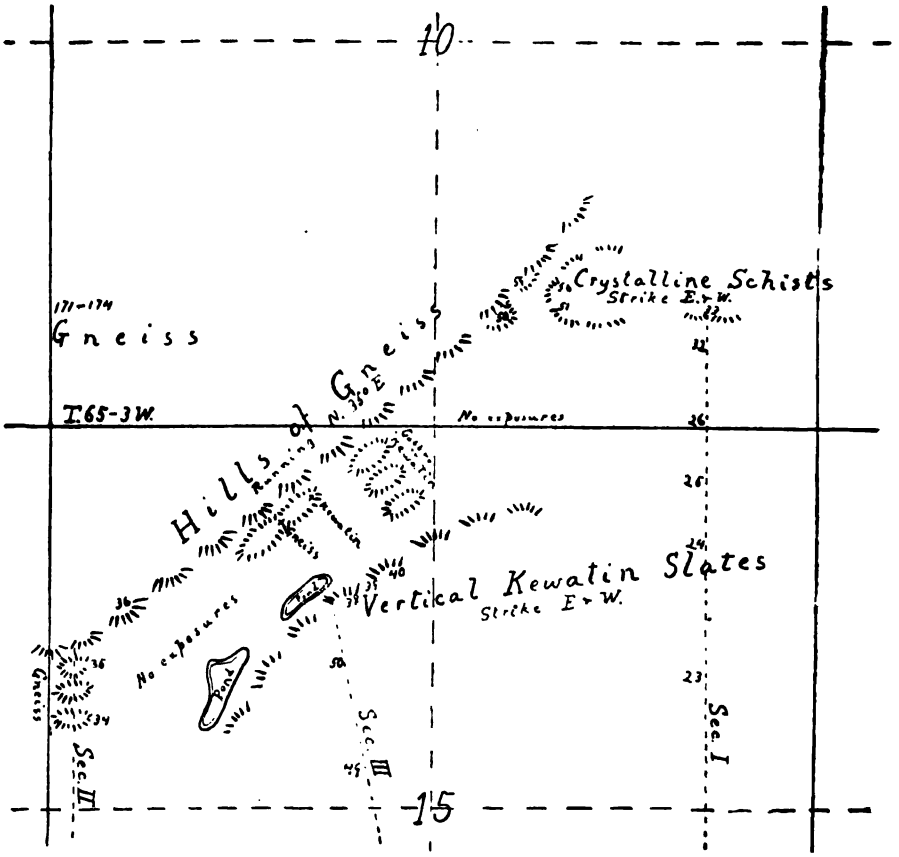


Fig. 2. Sketch showing the relation of the crystalline schists (Vermilion series) and Kewatin slates to the gneiss north of Gunflint lake.

Several pieces of micaceous schist were found in this gneiss; they were lenticular in shape and ran with the gneissic structure. The largest piece of schist was 10 feet long and 18 inches wide, and one end was irregular instead of running out to a point; No. 35 is from this piece.

A short distance east of the first observed gneiss is a trap dike, 20 feet wide, running N. 83° E. (Mag.) through the gneiss hills; this dike was traced for over 200 feet. The trap contained a few scattered crystals of feldspar, some of which are a quarter of an inch long; this rock is represented by No. 36. A mass, 3 feet in diameter, of trap quite rich in magnetite (No. 37) was found in this dike.

South of this range of gneiss hills is another range of hills made of Kewatin slates. At the place marked 38 in Fig. 2 the slates dip northward about 80°; the strike of all the slates is E. and W. (Mag.). Here the slate (No. 38) is interbedded with porphyrel (No. 39). About 100 feet east of this there is a dike of a soft schistose rock (No. 40) running parallel with the slate and porphyrel; this dike is 4 feet wide and was traced for 25 feet; it had split and inclosed a mass of the porphyrel (No. 42) which seems to have been changed by heat; the porphyrel at the contact has the same appearance as the inclosed mass. A part of the dike is much finer-grained than the rest, — this is shown by No. 41. This dike rock seems to have changed to a micaceous schist; the schistose structure runs with the length of the dike.

Extending from the slate hills to the gneiss range are three low hills composed of vertical slate, on top of which is gabbro; here the slate had been somewhat bent and broken, but the general strike was E. and W. (Mag.). Just west of these are two low hills running parallel with the gneiss range; near the eastern end of these hills is an exposure of vertical slate, striking E. and W. (Mag.); and between the two hills, and almost directly in the strike of the slate, is an exposure of gneiss. The last mentioned exposure of slate was within 100 feet of the gneiss hills. (See Fig. 2.)

Here we find a range of gneiss hills directly in the strike of the Kewatin slates; and the slate comes up to the gneiss, thus leaving no room for the belt of crystalline schists; subsequently the crystalline schists were found a short distance northeast of this place.

SECTION III: About 15° west of north, from the end of Kewatin bay (see map on page 255 of 16th An. Rep.) to the gneiss in the N. W. ¼ of sec. 15.

Forty feet from the lake is a hill, 200 feet wide, rising 40 feet above the water; the rock here is a vertical reddish-weathering schist (No. 47), striking N. 80° E. (Mag.). Six hundred feet beyond this is is another hill 300 feet wide; this is composed of vertical black flinty slate (No. 48) which weathers whitish; the strike on the south side of the hill is N. 78° E. (Mag.), and on the north side it is N. 82° E. (Mag.). After crossing a swamp we come to another hill about half a mile from the lake; here is a rather light-colored sericitic schist (No. 49) striking N. 85° E. (Mag.). About 600 feet beyond this is a large mass of gabbro (No. 50), very much decayed. And a few rods further are vertical slates striking E. and W. (Mag.). This brings us to the valley shown in Fig. 2.

Crossing over to the gneiss hills on the north of this valley and following them northeast for about 1,000 feet, we come to a large hill which is 400 feet wide (N. and S.); on the western and northwestern sides of this hill are numerous outcrops of vertical crystalline schists, striking E. and W. (Mag.). The specimens collected here are No. 51 to No. 56; these were found interbedded in the same manner as described in section I. No. 51 is a hornblende schist with a large quantity of feldspar. No. 52 has more hornblende. No. 53 is a fine dark mica-schist. Nos. 54, 55, and 56 are composed mostly of hornblende which is in quite large crystals. Directly west of this hill of crystalline schists is the gneiss range, and the outcrops on the lower ridges of this range are within 150 to 200 feet of the crystalline schists. One hundred and fifty feet W. S.-W. of 51 (Fig. 2) there is an outcrop of reddish syenite (No. 57), and 40 feet north of No. 57 the syenite is represented by No. 58; No. 57 does not show any decided gneissic structure, but this structure is very evident in No. 58; it is vertical and runs N. 85° E. (Mag.); No. 58A shows this very well. Two hundred feet from the schists and directly in the strike, the gneiss (No. 59) is again seen; the gneiss of the range of hills at this place is represented by this specimen.

The range of gneiss hills here extends northeastwardly and outcrops of gneiss can be seen for a quarter of a mile in that direction. The exact contact between the schists and gneiss could not be found.

Later in the summer, while at Gunflint lake, another trip was made to the locality described above. From the last mentioned exposure of crystalline schist I followed west over the gneiss range for nearly a mile and a half; thence south half a mile, and also north for a short distance; all the rock seen (there were many exposures) was the gneiss with the gneissic structure vertical and running nearly E. and W. At only one place was there any other rock seen; this was about three-fourths of a mile west of the schists; here the gneiss held many small pieces of dark homblendic rock represented by Nos. 170, 171, and 172. No. 170 is a dark, rather fine micaceous schist. No. 171 is coarser and shows no schistose structure. No. 172 is still coarse, have large crystals of hornblende; this rock is very similar to Nos. 27, 55, and 56. All of these specimens seem to be the same as the rock composing the crystalline schists. The pieces are mostly lenticular in shape, having the long axis east and west, but some were angular; they are collected quite thickly in a rather distinct area; on one side they disappear within ten inches, thus making a rather well defined line between the patch holding the foreign pieces and the rest of the gneiss; the other side of this patch is covered by soil, but 15 feet beyond the gneiss appears again. The rock in between the fragments contains no quartz (No. 173), but this rock gradually passes into the ordinary gneiss (No. 174) which contains large grains of quartz. This occurrence of foreign pieces in the gneiss much resembles the "conglomeritic syenite" of Saganaga lake described by Dr. Alexander Winchell in the sixteenth annual report, pages 219 and 334; also in the *American Geologist*, vol. III, No. 3, p. 153.

The facts noted in these three sections may be summarized as follows:

The crystalline schists show no evidences of having been twisted and bent,—the strike is quite constant and continues so up to within 200 feet of the gneiss; no outcrops were seen between this and the gneiss, low ground intervening. The slates in one place near the gneiss are somewhat crumpled, but this is only for a short distance and may have been caused by the gabbro which is found at that place. The crystalline schists (Vermilion series) and the slates (Kewatin) are cut across by a range of syenite gneiss hills which run N. 55° E. (Mag.). This syenite seems to be the same macroscopically as that, into which the crystalline schists pass conformably a few miles further east. The belt of crystalline schists, if continued in their strike would appear again, either on Gunflint lake north of the "narrows" or on the boundary river flowing north from the lake; but the schists are not seen here; all the rock seen for a number of miles north of the line between secs. 18 and 19, T. 65–3, along the lake and river shores (except a small area on the east side of Blackfly bay, which is Animike) is syenite, and there is no trace of the schists, unless, perhaps, it be a very few lenticular pieces of hornblende schist scattered in the syenite,—but these are found elsewhere in the syenite, far removed from any quantity of similar rock. From the facts noted it seems that the syenite has been pushed over or has flowed over the crystalline schists, or that there was a fault running N. E. and S. W. and the schist beds on the west side of this line have been pushed southwestwardly and now lie under the lake, or even further south than that. The situation of the rocks as shown by these sections is given in Fig. 2.

Iron location at Chub lake. This is in the N. E. ¼ of sec. 29, T. 65–4, and was visited in 1887 (see sixteenth annual report, pages 82 to 86). Since September, 1887, there seems to have been no working in the opening into the bluff on the north shore of the lake; No. 44 is a fair sample of the iron ore found at this place. A few rods west of this there is a steam engine and a large quantity of drill pipe. A diamond drill was worked here during the winter of 1887–8 by Mr. Millar of Grand Marais. The drill has gone down through the Pewabic quartzyte into the greenstone. A few pieces of the drill core (No. 45) were lying about; all of these seemed to be quartzyte, which in some places contained bands of a dark mineral, probably hornblende.

First falls north of Gunflint lake. These falls are in the boundary river in the N. E. ¼ of N. E. ¼ sec. 13, T. 65–4. The rock making the falls is the syenite gneiss (No. 62) of the region, with the gneissic structure running No. 80° E. (Mag.). On the Canadian side of the river is a diabase dike running N. 5° W. (Mag.); this is first seen at the waters edge on the upper (south) side of the falls. The dike rock is fairly represented by No. 61, but in some places it is finer grained, as shown by No. 61 A. After running north about 50 feet the dike suddenly ends,

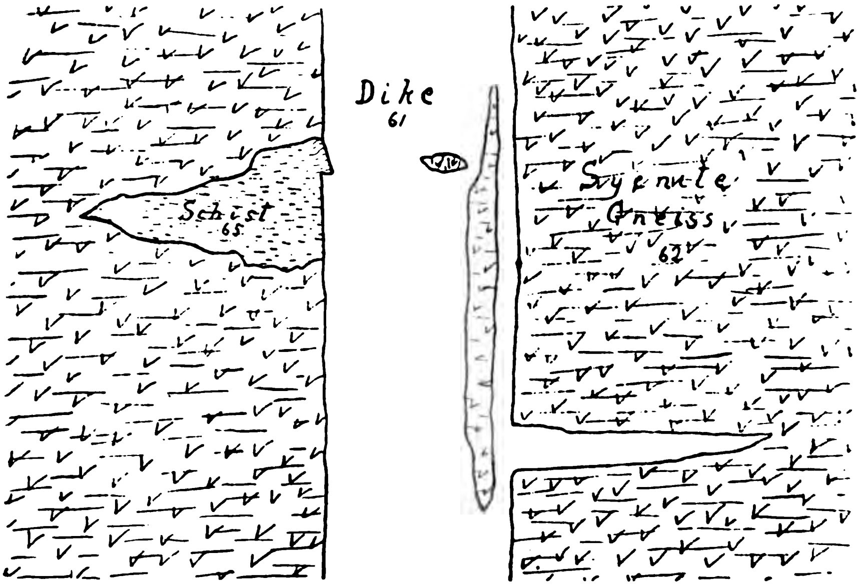


Fig. 3. Diabase dike in the syenite at the falls of the Boundary river, N. E. ¼ of N. E. ¼ sec 13, T. 65–4.

but a few feet east of this it is seen again and was traced northward for about 150 feet; here the rock contains more of a yellowish-green mineral, as is shown by No. 63; and in some places the surface is pitted (shown by No. 64) by the decay of one of the mineral constituents.

From this dike a spur, four inches wide, runs out into the syenite for four feet and ends in a point (see Fig. 3). Here is a piece of the syenite in the dike; this piece is eight feet long and four inches wide; the gneissic structure is parallel to that of the syenite through which the dike cuts. There is also a small lenticular piece of syenite in the dike, but in this the gneissic structure is at right angles to the other. A mass of hornblende schist (No. 65) is inclosed in the syenite, and one end of it is in contact with the dike, while the other end runs to a point; the schistose structure runs with the gneissic structure of the surrounding rock, but at one point (A, Fig. 3) it is slightly bent. By the firmness with which the piece of schist is connected with the syenite and by the looseness of its joint with the dike one concludes that the schist was in the syenite before the dike cut it; there is no part of the piece of schist on the other side of the dike. Several other smaller, lenticular pieces of hornblende schist, resembling the one above described and in no way connected with the dike, were found in the syenite near by.

OGISHKE-MUNCIE LAKE.

This lake lies in secs. 13, 23, 24, 26, and 27 of T. 65–6. The geology of its shores has been described in the former reports of the survey, but a few additional notes from one place are here given.

The place where these notes were taken is on the southeast shore of the lake, opposite the north end of the small island which lies just north of the narrows in sec. 24; or in the S. E. ¼ of N. E. ¼ of N. W. ¼ sec. 24. At the water's edge is a gray quartzyte (No. 76), probably the same as the gray quartzyte in the section given on page 371 of the fifteenth annual report; no bedding was seen in this quartzyte. A few feet from the shore are some vertical black slates (No. 77), striking N. 40° E. (Mag.); the contact between the slates and quartzyte was very distinct, and in one place the quartzyte extended across the strike of the slates. On the shore a few feet east of this place the quartzyte held a bed of slate about one foot wide and striking in the same direction as the other slates; on one side the slate bed by gradual change passed into the quartzyte, while on the other side the two were separated by a sharp line. These black slates contained many siliceous bands (shown in the specimens collected) which sometimes are an inch in width. No. 78 is from one of these bands; this seems to be a gritty sandstone with some calcareous matter in it; it effervesces slightly with cold hydrochloric acid. Going from the lake these bands increase in size and frequency and the black slate gradually disappears. The rock then grades through Nos. 79, 80, and 81 to No. 82 which contains some quartz grains but is chiefly made up of calcareous or dolomitic matter. The last four specimens were taken in a distance of fifteen feet; the rock all weathered with a vertical schistose structure which ran parallel to the strike of the black slate,—i. e. N. 40° E. (Mag.). Three feet beyond No. 82 the conglomerate (No. 83) occurred; the contact between the two was covered; the conglomerate seems to contain some of the dolomitic matter. The distance from the lake shore to the conglomerate was not more than thirty feet.

BIRCH LAKE.

This lake extends through the western part of T. 61–11, and the southern part of T. 61–12. During the summer of 1886 some observations were made along the Dunka river (see the fifteenth annual report, page 340), but there was not time to visit the high ridge south of the lake in secs. 7, 8, and 9, T. 60–12, and trace it eastward to the river; consequently the writer was instructed to examine this locality. The high ridge, which is made up of syenite, was visited by Mr. H. V. Winchell, and a full account of it can be found in his report. The notes here given were taken along the trail that runs south from the lake.

The mouth of Dunka river is near the centre of sec. 33, T. 61–12; the river is canoeable for about half a mile from the mouth; at the first rapids there is a trail running south. This trail crosses the river in the S. W. ¼ of sec. 10, T. 60–12; here the river flows over gabbro (No. 117) which contains some biotite. In one small area (about ten feet square) on the surface of the gabbro there are numerous, narrow dark bands; these are brought out very plainly by unequal weathering. The bands are parallel and vertical, running N. 35° W. (Mag.). Nos. 118 and 118A show these bands; the latter specimen was taken from a loose piece. About half a mile south of this place are many gabbro fragments (No. 119) which evidently came from rock in place near by. At the next crossing (S. W. ¼ of N. E. ¼ sec. 15) there are also some large gabbro fragments (No. 120). The river at this place flows through a swamp and no rock is exposed. Between the two crossings the trail is in many places covered with fallen trees and is difficult to follow.

Just west of the crossing in sec. 10 there is a low drift ridge; this runs a little south of west; it was followed one-fourth of a mile, where it turns more to the south and seems to disappear. A swamp extends westward from this hill, and about half a mile west of the crossing there is a low ridge, ten feet high and 300 feet long, running N. 20° E. This ridge is composed of a dark heavy quartzyte with bands of magnetite; the banding is quite regular and parallel and gives the rock a decidedly bedded appearance. The ridge runs with the strike of the quartzyte. The dip is S. 20° E. at an angle of about 30° (the direction of the dip is only estimated, as the needle was much disturbed). The specimens collected here are No. 115. This rock is probably the same as the olivinitic iron (No. 116) found on the trail in the N.W. ¼ of sec. 10 and mentioned on page 341 of the fifteenth annual report. What I have spoken of as a quartzyte is probably composed largely of olivine. The rock is a part of the Animike formation.

KAWISHIWI RIVER.

In T. 63–9. From the little bay in the S. W. ¼ of S. E. ¼ sec. 15, T. 63–9 there is a trail running northeast to the quarter post between secs. 14 and 15. On the shore the ordinary gabbro (No. 132) was found; it here held a few grains of magnetite. A quarter of a mile from the shore the trail crosses several small exposures of iron ore; these are surrounded by the gabbro; the ore is magnetite represented by No. 133, which was taken from the first of these ore exposures.

About sixty yards northwest of the quarter post between secs. 14 and 15 is a hill composed of a fine-grained rock (No. 134), which seems to be what the survey has called "muscovado." The east side of the hill is rather steep and here is some more of the magnetite (No. 135); this seems to lie under the muscovado, as it is exposed all along the base of the hill (about 250 feet) and just above and within ten feet of it the muscovado occurs in place. The contact between the two was not found. This outcrop of ore seems to be almost pure magnetite, but it occurs in the gabbro and very probably contains quite a large per cent of titanium, as all the gabbro ores do, and so would be comparatively worthless. The ore is exposed for about 250 feet and the exposure is ten feet high; the iron seems to extend under the hill indefinitely. The specimens collected fairly represent this ore.

After reaching the quarter post between secs. 14 and 15 the trail runs north on the section line to the northwest corner of sec. 14 and then east one mile, and then north on the line between secs. 11 and 12 to Snowbank lake. There are numerous exposures of rock, but it is all the ordinary gabbro. At one place a few small pieces of magnetite were seen in the gabbro. Iron was reported just west of the quarter post between secs. 11 and 12, but after search in this locality none was discovered.

Mr. Wm. Diarmid who has a claim in the N. ½ of S. W. ¼ sec. 3, T. 63–9, says that there is an outcrop of magnetite in the gabbro near the quarter post between secs. 13 and 14, T. 63–9; also one in the S. E. ¼ of sec. 7, T. 63–8. He also mentioned outcrops of jasper in the N. E. ¼ of sec. 8, T. 63–9 and in the N. W. ¼ of sec. 4. These localities were not visited by the writer, but Mr. H. V. Winchell examined the jasper in T. 63–9 later in the season.

South of Mishiwishiwi lake. The Indians apply this name to the lake, which the survey called Bald Eagle lake in the fifteenth annual report; the lake lies mostly in secs. 25, 26, and 36 of T 62–10. A river flows into the southeastern corner of the lake, and about a mile from the mouth of the river, or in the N. W. ¼ of sec. 5, T. 61–9, there is a stream flowing into the river from the south; this stream is canoeable for about a mile and a half. On the right bank of the stream and an eighth of a mile south of its mouth is a hill of gabbro, which appears to be the west end of a low ridge running east and west. This gabbro (No. 136) has a gneissic structure, which is vertical and runs N. 15° W. (Mag.), making the rock break more readily in this direction than in any other. In some places the gabbro lies in horizontal beds from two to four inches thick. The rock seems to be almost entirely composed of a feldspar (probably labradorite) and a mineral which is probably olivine; this, when not decayed, is of a yellowish-green color, but its hardness is below 6. A few rods further south, on the left bank of the stream is a small hill of the some gabbro showing the gneissic structure running in the same direction,—i. e. N. 15° W. (Mag.).

About a third of a mile south of the last mentioned hill is another gabbro hill on the left bank of the stream. The rock here is similar in composition to that above described, but is coarser grained and does not have the gneissic structure seen in the other; but many of the weathered surfaces have a peculiar banding, which is caused by the feldspar crystals being aggregated in certain lines that are vertical and run N. 10° W. (Mag.). No. 138 is a fair sample of the gabbro from this locality, while No. 137 shows the banding. The olivine, as it decays, loses its yellowish-green color and becomes darker (sometimes having a deep red color, like garnet) until on the weathered surface of the rock it appears as rusty spots. The decay of the olivine causes the rock to crumble and be easily shattered. From this hill a higher range, running east and west, could be seen about ten miles to the south.

A mile and a half from its mouth the stream narrows and rapids soon occur; here is a poor, not recently used, portage on the left side of the stream; beyond this portage the stream is crossed by many fallen logs, so we went no further.

About a mile and a half south of this place the low rounded hills, a form common to a gabbro country, seem to be collected into a low range that runs east and west. The country south of Mishiwishiwi lake has been burnt and is now partially covered by small poplars and birches, although many of the hills are treeless.

The small lake in sec. 32, *T.* 63–10. A small island near the southern shore of this lake is composed of a red syenitic gneiss (No. 139), the gneissic structure being very easily seen on the weathered surfaces and running N. 50° E. (Mag.). A little north of this is another island composed of about the same syenite, but this (No. 140) does not show the gneissic structure. These islands are in the N. E. ¼ of S. W. ¼ sec. 32. On the west side of the little bay, which is in the N. W. ¼ of N. W. ¼ sec. 32, the syenite is lighter colored and has large crystals of hornblende as shown by No. 141. At the portage, in the N. E. ¼ of N. E. ¼ sec. 31 there is a light gray gneiss (No. 142) with the gneissic structure running N. 60° E. (Mag.); this gneiss holds pieces of a darker rock (No. 143), and seems to be mixed in with a mica schist and a hornblende schist a few feet south of the portage. On a little point, near where the line between secs. 31 and 32 crosses the southern shore of the lake, there is red syenite like No. 139. There was not time to examine the whole lake, but the shores seemed to be made up of syenite, of which No. 140 is a fair sample.

Mr. H. V. Winchell found the rock on the southern (?) shore of this lake to be a dark hornblende rock (No. 144), which grades into the ordinary syenite through No. 145 and No. 146.

LAKE ISABELLE.*

This lake lies in secs. 25, 35, and 36 of T. 62–8 and secs. 30 and 31 of T. 62–7.

On the west shore of the little bay in the S. W. ¼ of N. W. ¼ of sec. 35, the gabbro is composed principally of labradorite with a small amount of a glassy yellow mineral (probably olivine) and magnetite, which seems to cause the rusty spots near the surface of the rock; a few scales of biotite are also present; this gabbro is represented by No. 147. A few rods further north there is an irregular vein of granulyte (No. 148) in the gabbro; the vein is eight inches wide; one of the specimens collected shows both the vein rock and the gabbro; in the vein rock there are a few scattered scales of biotite.

On the west side of the larger bay, which is in the N. W. ¼ of sec. 35, there is a perpendicular cliff (5 to 15 feet high) of gabbro (No. 149) that is coarser grained and contains considerable olivine, but some of this yellow color may be due to a decayed condition of the labradorite. At the head of this bay, gabbro similar to No. 149 occurs.

On the shore in the S. W ¼ of N. E. ¼ sec. 35 there is a dark, heavy, fine-grained trap rock (No. 150) which gives a metallic ring when struck by the hammer; this grades into No. 151 which is coarser. A few rods back from the shore Nos. 152 and 153 were found in low outcrops; these seem to be but different conditions of No. 150. No. 152 contains considerable magnetite. A little further north on the shore this rock contains small patches of biotite, as shown by Nos. 154 and 155, the latter being a decayed condition of the former. These grade into No. 156 which is coarser. On the shore, a few steps north of No. 156, this rock (trap) is found in contact with the gabbro (N. ½ of N. E. ¼ sec. 35); the line of contact was not always distinct and in some places, as near as could be determined from the smooth-weathered surface, the transition from one rock to the other occupied two or three inches. No. 157 represents the trap near the contact with the gabbro.

---

*Only the north shore of this lake is here described; for the description of the rest of the lake, and also of most of the country between here and lake Superior (this lake and the two following being the only ones here mentioned), consult the report of Mr. H. V. Winchell.

The rest of the north shore of the lake has many gabbro outcrops; for long distances there are smooth, flat exposures of gabbro rising but a few inches above the water and extending back for several yards from the shore. Three dikes are found cutting the gabbro. The first is in the N. E. ¼ of N. E. ¼ sec. 35; this dike is twenty inches wide and was traced for over sixty feet; it runs N. 30° W. (Mag.); the rock is a very fine diabase (No. 158); the contact with the gabbro is distinct. This dike occurs only a few rods north of the contact mentioned, about ten lines above. The second dike is in the S. W. ¼ of sec. 30, T. 62–7, is twenty feet wide, and could be traced only twenty-five feet, as the water covered it on one end and the soil on the other; the rock is diabase and is represented by No. 159, which was taken from the centre of the dike, and by No. 160, which was taken from one side (only one side of the dike was finely crystalline); No. 160 appears to be the same as No. 158; the contact is distinct. The third dike is in the W. ½ of sec. 31, T. 62–7 and is composed of a fine diabase represented by No. 161; this dike is fourteen inches wide and can be traced only a few feet.

BELLISSIMA LAKE.

This lake lies in the southeastern corner of T. 61–7. The north shore was examined by the writer. The shore is usually lined with boulders, most of which are large gabbro boulders, the others are smaller and apparently come from the drift; some of the latter are probably from Cupriferous rocks. Wherever the rock was exposed it was found to be very coarse labradorite gabbro, as shown by No. 162, which was obtained on the shore, about half a mile east of the west end of the lake. The north shore was low and there were no hills near the lake. No glacial striæ were seen.

PINE LAKE.

This lake lies in the S. W. ¼ of sec. 21 and in the N. W. ¼ of sec. 28, T. 60–6.

On the north shore, about one-fourth mile east of the portage from lake Harriet (just west of Pine lake), is a low rock outcrop at the water's edge; this outcrop is about twenty feet square. The rock is of three kinds; (1) a gray rock (No. 163) composed mainly of a gray feldspar; (2) a red rock (No. 164) made up of quartz and red feldspar; (3) a very fine dark trap (No. 165) holding crystals of red feldspar. No. 164A shows a darker and more siliceous condition of No. 164. Nos. 164 and 165 are very much mixed, each containing pieces of the other (see Nos. 164, 165, 165 A, and 165B). No. 163 is not found mixed with the others, but it contains a few small pieces of a dark siliceous rock as shown by No. 163A. No. 163B is intermediate between No. 163 and No. 164. The dark trap much resembles some of the trap of the Cupriferous; it is split by numerous parallel planes that are vertical and run N. 5° W. (Mag.); these are shown by the specimens.

A diabasic rock (No. 166) outcrops on the east shore near the southern end of the lake; it holds a few scattering crystals of feldspar which are sometimes nearly an inch long. This outcrop and the one mentioned above are the only two outcrops on the north and east shores of the lake.

Mr. H. V. Winchell reports several outcrops of fine diabase on the west shore of the lake; Nos. 167, 168, and 169 represent this; they seem to differ only in fineness, and all of them are much finer than that from the east shore.

The notes from Mayhew to Flying Cloud lake (inclusive) were taken on a trip from Gunflint lake south to Brulé lake and then north and west through townships 63–4, 64–4, 65–4, 65–5, and 65–6 to Ogishke-Muncie lake. The object of this trip was to examine reported iron ore locations, most of which were not found as reported,— there usually being no ore to be seen. The country passed over is one not usually traveled by white men and is seldom used by Indians except in winter; consequently the portages are very poor and badly cut, it oftentimes being necessary to go ahead and recut a portage before the canoe could be taken across. This fact, together with the fact that the township plats were very inaccurate, caused much unavoidable delay and waste of time. There are, however, some fair portages; those from Gaskanas lake to Brulé lake are quite good, and the portages from lake Ida Belle north to the lake in the S. W. ¼ of sec. 35, T. 65–4 are wide and well cut out, being used as winter roads by the Indians.

Several of the lakes on this trip were given names, as they have none on the township plats nor on any of the maps accessible. It must be admitted that this is rather a bad principle to follow, the right way being to give them the names by which they are known to the native Indians or, better still, to give the English equivalents of the Indian names; but, as the Indian names were not obtained, it was thought best to have some name by which each lake could be known. The lakes thus named are Straight, Meed's, Stray, Sham, Lost, Georgia, Surveyor's, Found, Ida Belle, Narrow, Round, and Draper lakes.

MAYHEW LAKE.

Mayhew lake is a narrow strip of water, about one-fourth of a mile wide and a mile long, extending east and west through the south half of sec. 36, T. 65-3. It is 305 feet above Gunflint lake. A rough, steep portage runs from Loon lake to Mayhew lake.

The ordinary labradorite gabbro (No. 175) is seen on the south shore in S. W. ¼ of S. E. ¼ sec. 36. On the end of the little point, which is in the S. E. ¼ of S. E. ¼ sec. 36, the gabbro (No. 176) has changed somewhat, and on the south side of this point it surrounds a large mass of iron ore. This ore (No. 177) seems to be principally magnetite, with a little scattering feldspar, but, as it is in the gabbro, it very probably contains a considerable amount of titanium. The exposure of ore was 30 feet wide and extended for about 300 feet along the shore, rising 15 feet above the water. The contact between the ore and gabbro was found at one place; here the gabbro does not pass into the iron ore by gradually acquiring more magnetite, but there is a sharp and distinct line between the two.

There is a trail, on the town line, running south from the lake; this trail was followed nearly three-quarters of a mile, and several gabbro ridges, running east and west, were crossed; the gabbro is much decayed and is nearly half made up of magnetite (No. 178). From the town corner (T. 65-2, 65-3, 64-2, and 64-3) a trail runs west along the line between townships 64 and 63. About a quarter of a mile west of the corner, and just south of the line, there is a small lake; here were seen many fresh beaver gnawings. Gabbro was the only rock seen on this trail (it was followed no further than the small lake mentioned above).

IRON LAKE.

This lake is a narrow body of water extending through the south half of secs. 31, 32, and 33 of T. 65-2. It is the same hight as Mayhew lake, and the two are connected by a narrow strip of water, 60 or more feet in width.

The point, which is crossed by the line between secs. 31 and 32, also the north shore of the lake in the south half of sec. 32, were examined in order to see the iron ore at these places. (This lake was described in the tenth annual report, page 80.) The point was crossed twice west of the section line and once east of it, but no ore was found except a seam of magnetite (containing a little feldspar) eight inches wide and twelve feet long, and a few small masses (No. 179) of the same in the gabbro. A low ridge of gabbro runs along the southern shore of this point, and in this ridge the magnetite was found. The gabbro is, in places, quite rich in magnetite; this is shown by No. 180, which was taken near the section line. Four sections of a quarter of a mile each were made north of the lake in sec. 32, but no ore was found. The rock was all gabbro, and none of it contained as much iron as No. 180. The shores of Iron lake are usually lined with gabbro.

PORTAGE LAKE.

Portage lake is mostly in the north half of sec. 4, T. 64-2, but an arm extends east for half a mile in sec. 5, and the line between T. 64 and 65 crosses the northern part of the lake, making a small portion of it in sec. 33, T. 65-2. It is 25 feet above Iron and Mayhew lakes.

In the S. E. ¼ of N. W. ¼ sec. 4, on the shore, is an exposure of a fine "muscovado" (No. 181); one of the specimens collected shows a porphyritic crystal which is probably labradorite. The relation of this rock to the gabbro could not be found at this place. On the south shore, in the N. E. ¼ of N. E. ¼ sec. 4, there is an exposure where the gabbro and "muscovado" were found together. The former held several large masses of the latter rock that looked like dikes, but they could not be traced far enough to determine that they were dikes. There was one lenticular piece of "muscovado" (15 inches long) in the gabbro, and in places the gabbro held pieces of the other rocks in which were small bits of the gabbro. The bottom of the exposure was entirely of gabbro. It could not be positively ascertained which was the older of the two rocks, but the "muscovado" seems to have broken up through the gabbro.

On the south shore, in the N. W. ¼ of N. W. ¼ sec. 3, the gabbro is in distinct beds from two to eight inches thick and dipping south about 30°. This bedded structure, dipping in the same direction and at about the same angle, was noticed several times, but at no other place were the beds as thin and as distinct as here. The gabbro was seen at several other places on the south shore of the lake.

POPLAR LAKE.

This lake lies mostly in secs. 1 and 12 of T. 64–2 and secs. 7 and 8 of T. 64–1; a small portion is in sec. 6, T. 64–1, and a narrow bay extends into the S. E. ¼ of sec. 2, T. 64–2. It is 20 feet below Portage lake. A portage leads from the east arm of Portage lake to the extreme northwestern point of Poplar lake; the trail is rather plain at the western end, but at the other end there is almost no trail at all. No one seems to have been over the portage for two or three years. No portage could be found leading to Duck lake (a small lake in the eastern part of sec. 3, T. 64–2) mentioned by N. H. Winchell in the tenth annual report, page 79.

Gabbro was seen in several places on the portage from Portage lake. On the little point in the N. W. ¼ of N. E. ¼ of N. W. ¼ sec. 12, T. 64–2, the gabbro is finer than is usually found. At this place it varied from No. 182 to No. 183; the former shows a gneissic arrangement of the minerals, but this is not constant. On the shore in the S. E. ¼ of N. E. ¼ sec. 12 the gabbro (No. 184) has the labradorite collected together in spots, but this soon grades into the ordinary gabbro.

STRAIGHT LAKE.

This is a small, narrow lake, half a mile long and 100 yards wide, extending northwest and south east in the S. W. ¼ of sec. 7, and the N. W. ¼ of sec. 18, T. 64–1. It is 25 feet below Poplar lake and is not shown on the township plat. The portage starts from Poplar lake on the range line and runs a little east of south; it is about one-fourth mile long. Gabbro was seen on the portage.

CARIBOU LAKE.

Caribou lake is in sec. 18, T. 64–1 and sec. 13, T. 64–2. It is ten feet below Straight lake. The portage from the latter lake is a quarter of a mile long. Gabbro occurs on Caribou lake at the portage and was also noticed in several places along the north shore. There is a claim cabin in the S. W. ¼ of N. E. ¼ sec. 13, T. 64–2, probably built within the last year, and from this cabin a line ran north for one-fourth mile; no rock was found except some gabbro at the north end of this line. The south and west shores and some of the islands of this lake have not been burnt, but all the country passed through since leaving Loon lake was burnt a number of years ago and is now covered with a not very dense growth of poplars and birches, usually not more than 25 feet high.

MEED'S LAKE.

Meed's lake is less than half a mile wide, and extends through the northern part of secs. 14 and 15 into secs. 13 and 16 of T. 64-2. It is 10 feet above Caribou lake. The timber along the shores is very dense, composed mostly of spruce, and extends down to the water's edge. No portage could be found from Caribou lake to this lake, so it was necessary to portage up the creek bed (S. E. ¼ of N. W. ¼ sec. 13, T. 64-2) for 100 yards, where the creek widens into a pond, and from the west end of this pond 200 yards more to Meed's lake. There is no high land to be seen from this lake except a hill, 90 feet above the water, in the N. E. ¼ of N. W. ¼ sec. 15.

On the geological map in the fifteenth annual report iron ore is marked all along the north shore of this lake, but, after careful search, none was found. The north shore of the lake was examined and no rock was seen except several outcrops of gabbro. Several trips were made north from the shore, as follows: (1) One-fourth mile north, a little west of the centre of sec. 15; a hill of gabbro (No. 185), mentioned above, was the only rock found. (2) Mr. Meeds went more than half a mile north about one-fourth mile west of the line between secs. 14 and 15; he reported several outcrops of gabbro. (3) One-half mile north from the little bay which extends into the S. W. ¼ of S. W. ¼ sec. 11; no rock found in place except a little gabbro at the shore. (4) From the east side of this little bay where the line between secs. 11 and 14 crosses the shore, northeast one-third mile, and then south to the lake shore. Several low ridges of gabbro, running east and west, were crossed. On the way south to the lake a small exposure of almost flat-lying (dipping S. 4°), bedded rock was found. This exposure was not more than six feet across; the rock is similar to some of the Animike beds of Gunflint lake and vicinity. One specimen (No. 186) was collected; this has a structure somewhat resembling öolite; pieces of this are quite common on the beaches of Gunflint lake. The rock is undoubtedly Animike, but I was unable to determine whether it was in place. Search was made for more of this rock, but none was found.

NORTH BRULÉ LAKE.

There is a portage starting from Caribou lake a little west of the line between ranges 1 and 2 and running south a quarter of a mile to the northwestern arm of North Brulé lake. North Brulé lake is a very irregular body of water lying in secs. 19, 20 and 29 of T. 64–1 and sec. 24 of T. 64–2. It is 20 feet below Caribou lake. Only that part of the northwestern arm lying in the N. E. ¼ of sec. 24, T. 64–2, was examined; here gabbro was seen in two outcrops. The shore has not been burnt and is covered mostly by spruce and cedar.

STRAY LAKE.

This lake is long and narrow; it lies in the north half of sec. 24, T. 64–2 and extends nearly half a mile into sec. 23. It is 30 feet above North Brulé lake. The portage leading from the last lake to Stray lake starts almost directly south of the one from Caribou lake. Gabbro was seen on this portage and also along the stream that flows from Stray lake to North Brulé lake.

GASKANAS LAKE.*

This lake is nearly three miles long, and not more than half a mile in width. It lies in secs. 22, 23, 24, 25, 26, and 27 of T. 64–2, and is 15 feet above Stray lake. We could find no portage leading south from Stray lake and so cut one to the pond which is in the S. W. ¼ of sec. 24. From this pond an old and poorly-cut portage leads to Gaskanas lake. Gabbro was seen at each end of the last portage, also on the east side of the little bay in the S. E. ¼ of N. W. ¼ sec. 26. This lake is a very pretty little sheet of water and is dotted with many green islands. The shores are densely wooded and along the south shore, especially in sec. 26 where there are two claim cabins, there is considerable good white pine.

---

*This name is taken from Heinze Bros.' "Map of the Vermilion Iron Range." This map gives Winchell lake as Ababikaigan lake.

WINCHELL LAKE.*

Winchell lake is a long, narrow body of water, over five miles in length and less than half a mile in width, extending east and west in the southern part of T. 64-2 and running half a mile into T. 64-3. It is 30 feet above Gaskanas lake. The portage from Gaskanas lake (this starts from the bay in S. E. ¼ of N. W. ¼ sec. 26) is very good,—the first good one seen since leaving Gunflint lake. The water of Winchell lake is deep and very clear; the shores are well covered with timber which is composed mostly of spruce and birch with some scattering white pine. The Grand Marais Indians call this Mountain lake, probably because of the high ridge that extends along the south shore.

Gabbro occurs in place at the portage in the N. E. ¼ of S. W ¼ sec. 26, T. 64-2, and there are outcrops of rock (apparently gabbro) all along the north shore, but only one of these was visited; here (S. E. ¼ of S. E. ¼ sec. 29) the gabbro (No. 187) is like the ordinary labradorite gabbro found further north, but is a little finer. We followed along the south shore of the lake, but no rock outcrops were seen until we came to the point which is crossed by the line between secs. 31 and 32, T. 64-2; here a high ridge, which extends all along the south shore of the lake and rises 50 to 100 feet above the water, comes to the shore and forms a precipitous cliff nearly 100 feet high. This cliff is composed of gabbro (No. 188) which differs from the ordinary gabbro in that it contains a considerable amount of a whitish feldspar mixed with the labradorite. The gabbro extends along the shore for a quarter of a mile west of this point.

In the N. W. ¼ of N. W. ¼ sec. 31, T. 64-2, the above mentioned ridge is cut by a small stream flowing from Sham lake, which is just south of Winchell lake. Just east of this stream is a bluff rising 80 feet above the water. The rock at the foot of the bluff is covered by large angular masses of rock that have fallen down from higher up. The first rock seen *in situ* is almost 20 feet above the water level; it is gabbro (No. 189) that is like the ordinary labradorite gabbro, except that it is more compact and contains a little light-colored feldspar. Twenty feet higher up the gabbro is represented by No. 190; this is similar to No. 189, but has more of the light-colored (pinkish) feldspar. This feldspar increased until, ten feet above No. 190, the rock was largely composed of it. This rock (No. 191) has a red color and seems to be the gabbro changed by heat; this could not have been done by forest fires as none have passed over the shore. The feldspar crystals vary all the way from the dark (almost black) labradorite through white to a decided red. This rock is about as coarse and, with the exception of color, has the same appearance as the ordinary gabbro. None of the specimens above mentioned contain any quartz. Two feet above No. 191 the rock is very dark and tough, being composed mostly of a black mineral probably hornblende, which is not always in definite crystals; this gives the rock (Nos. 192 and 193) the appearance of having a dark compact ground mass in which are scattered blotches of pinkish feldspar; in these feldspar blotches there are numerous small quartz grains. A little higher up occurred a fine pinkish gray syenite (No. 194). No. 195 was taken just above this and No. 196 from the top of the bluff. The latter is coarser and is a distinct syenite. On examining the bluff at another place the syenite was found at the top and the gabbro near the bottom. Among the angular pieces at the foot of the bluff one (No. 197) was found which seems to be intermediate between the highest gabbro (No. 191) and the syenite; it resembles No. 191 and, like it, has labradorite (?) crystals, but it also contains numerous quartz grains while No. 191 has none. On the north end of the portage to Sham lake the rock is a condition of the gabbro,— No. 198.

---

*This name is taken from Reisenegger's map of Northeastern Minnesota.

The above mentioned bluff shows an apparent transition from the gabbro at the bottom (No. 189) to the syenite at the top (No. 196), *the syenite lying on the gabbro.* The change is gradual, and rapid at only one place — between No. 191 and No. 192; here the transition occurs within two feet; the quartz in No. 192 is in such small grains that it was not noticed in the field, so the exact place where the quartz first appears was not determined; however, there is no distinct contact line between these two rocks, but the change from one to the other is quite sudden. It seems that the syenite is of igneous origin and has flowed out over the gabbro, the gabbro being changed somewhat by molten rock above it. No. 191 represents the changed state of the gabbro and No. 192 is the first, or lowest, part of the syenite; at any rate the change occurs between these two,— the distinct labradorite crystals disappearing and the quartz coming in.

SHAM LAKE.

This is a small lake, less than a mile long, on the line between sec. 31, T. 64–2 and sec. 36, T. 64–3. It is 15 feet above Winchell lake and is connected with it by a small stream which is a short distance east of the range line. The portage between the two lakes is less than one-eighth of a mile in length. Sham lake has no long arm extending west through sec. 36, as is shown on the township plat.

The rock at the south end of the portage is represented by No. 199; this is similar to No. 192 except that the hornblende is in distinct crystals and the quartz is not very plentiful. On the east side of the lake, in the S. W. ¼ of N. W. ¼ sec. 31, a fine red syenite (No. 200) occurs; it is composed of a red feldspar and hornblende, the feldspar making up about two-thirds of the rock; no quartz can be seen with a hand lens, but it probably contains some. The rock is probably the same as the fine red syenite or "red rock" found by Prof. N. H. Winchell both east and west of this place. Near the southwest corner of the lake, in S. E. ¼ of S. E. ¼ sec. 36, there is a low outcrop of a rock (No. 201), apparently part of the transition from gabbro to syenite; it resembles Nos. 192 and 193 from Winchell lake.

LOST LAKE.

From the south end of Sham lake there is a portage running S. S. W. for about a mile to Lost lake. This lake is not given on the township plat, and as near as could be determined it lies in the S. ½ of sec. 1 and the N. ½ of sec. 12, T. 63-3. It is about half a mile long (N. and S.) and a quarter of a mile wide. The shores are well wooded and have considerable good white pine. This lake is 30 feet above Sham lake.

On the portage from Sham lake the fine red syenite, same as No. 200, occurs in several places just east of the trail. On the west side of the lake, in S. E. ¼ of S. W. ¼ sec. 1, there is a high bluff of this same syenite; and many angular pieces have fallen down making a large talus; at this place the rock is represented by No. 202, which is of a brick-red color and contains even less hornblende than No. 200.

BRULE LAKE.

From Lost lake there is a portage of a quarter of a mile running S. S. W. to a small lake, not shown on the township plat, in the W. ½ of sec. 12, T. 63–3. This small lake is about a quarter of a mile in length. From its southern end a portage of less than a quarter of a mile leads to the bay of Brulé lake that extends into the S. W. ¼ of sec. 12, T. 63–3.

Brulé lake is the largest lake seen since leaving Gunflint lake, —in fact it is the largest lake in Minnesota south of the boundary and east of range 9. It is seven miles long, the average width being a mile, and extends through the central part of T. 63–3 and a mile and a half into the western part of T. 63–2 (that portion of the lake in this township was not visited). The north and west shores have not been burnt; here is some good white pine. The southern shore was burnt some years ago and is now covered with a second growth of birches. There is a claim cabin on the point in the N. E. ¼ of N. W. ¼ sec. 13, and from a Grand Marais Indian, we learned that there were several more about the lake. Brulé lake is 75 feet below Lost lake. The water is cle and deep.

In the S. E. ¼ of S. W. ¼ sec. 12, at the water's edge, there is a low exposure of a dark siliceous trap rock (No. 203), which appears to be perfectly homogeneous under the hand lens. This rock contains a few small crystals of iron pyrites. No bedding structure could be seen but there were many small joints cutting the rock; in one place these were parallel and dipped south about 20°. A little further south along the east shore of this bay (the bay in the S. W. ¼ of sec. 12) is an outcrop of a rock (No. 204) composed almost entirely of plagioclase feldspar crystals of all sizes up to half an inch in length; these crystals seem to be imbedded in a dark, finely crystalline matrix, but this is a very small part of the rock.

On the point in the S. E. ¼ of N. E. ¼ of N. W. ¼ sec. 13 the rock at the water's edge is a white feldspar porphyry (No. 205); the feldspar crystals run up to those an inch in length; the matrix is dark and finely crystalline; it makes up about one-half of the rock. No. 204 is probably a condition of this porphyry. Ten feet above No. 205 and 30 feet back from the shore there is another feldspar porphyry (No. 206); this seems to be different from No. 205, as the matrix is much finer, darker and apparently more siliceous, and the feldspar crystals, instead of being white, are of a dull reddish-brown color; the matrix comprises about three-fourths of the rock; the feldspar crystals weather white. The rock between these two porphyries is covered by soil.

A few yards south of No. 206 is a small exposure of a brick-red rock (No. 207) which is composed of a reddish, homogeneous and siliceous ground-mass, in which are small crystals of a brick-red feldspar, a dark mineral (probably hornblende) and quartz. This rock might be called a quartz porphyry and is entirely different from any of the others on this point. It is cut by many parallel planes (shown in the specimen) which are vertical and run east and west. On the north side of this exposure the red rock is in contact with a fine diabase (No. 208); the contact line is distinct but was exposed for only a few inches; where seen it was vertical and ran east and west. Near the contact the ground-mass of No. 207 becomes darker and more siliceous; this is shown by No. 207A.

Where the line between secs. 13 and 14 strikes the north shore the rock is similar to No. 204. This same rock occurs on the point in the N. W. ¼ of N. E. ¼ sec. 14 and also on the small island just south of this point. The shore was not examined again until reaching the large island in the centre of sec. 17; no outcrops were seen along the south shore of this island. On a small island in the S. E. ¼ of S. E. ¼ sec. 18 there is a dark, diabase-like rock inclined to be amygdaloidal (No. 209); this is quite finely crystalline and inclines to a dark purple color. In places in this rock there are small blotches of a reddish feldspar; the centre of each blotch is composed of a dark mineral, probably hornblende. This rock also occurs near the west end of the island that is cut by the line between secs. 17 and 18, and on the east end of the portage towards Georgia lake.

It is to be regretted that we were unable to more carefully examine the relations of the rocks from the south shore of Winchell lake, to and through Brulé lake, but our provisions would not warrant a longer stay.

LAKE GEORGIA.

This lake lies in the W. ½ of sec. 18, T. 63-3, and sec. 13, T. 63-4, and small bays run into secs. 14 and 24. It is 6 feet below Brulé lake. The shores have been burnt and are now covered with small birches and poplars. A stream flows from Brulé lake to lake Georgia and the portage between the two lakes is in the S. W. ¼ of sec. 18; it is only 200 feet, and not a quarter of a mile, as shown on the plat. Lake Georgia has no arm extending into sec. 12, T. 63-4, as is shown on the government plat.

In the north branch of the arm that extends into the S. W. ¼ of sec. 18, a short distance west of the portage from Brule lake, there is a rock (No. 210) which appears to be a condition of the gabbro. A little west of this, and on the north shore of this arm, is an outcrop of a feldspar porphyry (No. 211); this seems to be somewhat similar to No. 206; the feldspar crystals are reddish, but rather scattered — probably making up not more than one-tenth of the rock. On the north shore of the lake in the N. E. ¼ of S. W. ¼ sec. 13, T. 63–4, there is a trap rock (No. 212); which is in contact with the gabbro, here represented by No. 213; the two specimens were taken within three feet of each other; the contact line was covered by soil. No. 212A shows the trap further from the contact; it is much coarser than No. 212. Gabbro also occurs where the line between secs. 13 and 14, T. 63–4 touches the northern shore of the lake.

SURVEYOR'S LAKE.

This lake is in sec. 12, T. 63–4. It is shown on the township plat as an arm of lake Georgia, but there is no connection between the two except a small stream flowing from Surveyor's lake; the portage between these lakes is in the N. E. ¼ of sec. 13 and is over an eighth of a mile long. The aneroid shows no difference in hight between the two lakes, but Surveyor's lake is a little higher than the other. North and east of this lake are hills 50 to 100 feet high.

In the S. W. ¼ of sec. 12 there is a deep bay running west for nearly half a mile. At the end of this bay on the portage going west to Found lake is a fine red syenite (No. 214), similar to Nos. 200 and 202. There is a ridge extending along the north side of this bay; the red rock (syenite) in the ridge can be seen from the lake.

FOUND LAKE.

Found lake is in the S. ½ of sec. 11, T. 63–4. It is a small lake, less than half a mile long (east and west) and is not shown on the township plat. The shores have been burnt and are now covered with a second growth of birch and poplar. This lake is the same hight as Surveyor's lake.

The fine red syenite, similiar to No. 214, occurs in several places on the portage from Surveyor's lake. On the north side of the lake is a hill, 50 feet above the water, composed of a diabase (No. 215). On each side of this hill the red syenite occurs, thus making it seem as if the diabase had cut through the syenite; the two rocks were not seen in contact. The north shore of the lake is mostly made up of the fine red syenite. In one place this syenite held angular pieces (none were seen over three inches in diameter) of a fine dark rock; this is shown by No. 216, which shows both the dark rock and the syenite. In this specimen the syenite is easily seen to contain much quartz;— in the other specimens of this syenite (Nos. 200, 202, and 212) quartz can not be clearly seen with the hand lens.

LAKE IDA BELLE.

This lake is very irregular. It lies in secs. 1, 2, 3, 10, 11, and 12 of T. 63–4, while bays extend a short distance into T. 64–4, T. 64–2, and T. 63–3. It is 30 feet below Found lake. The country around lake Ida Belle, except a small portion at the northeast corner of the lake, has been burnt, and there are vast exposures of rock all around the lake not yet covered by a second growth of trees.

This lake lies in the great gabbro sheet; probably nine-tenths of the rock around the lake is gabbro, the rest being trap and fine red syenite. A belt of iron ore was reported running from sec. 1 to sec. 18, T. 63–4; the entire lake shore was examined, also part of the country southwest of the lake, but no iron ore was found;—in fact the only iron seen consisted of a few bands or seams of magnetite in the gabbro. Fresh beaver cuttings were seen along the shore in sec. 10, T. 63–4. No portage could be found from the last lake to lake Ida Belle, and so one was cut straight north for about one-third of a mile; this brought us to lake Ida Belle near the centre of Sec. 11, T. 63–4.

In the S. W. ¼ of N. E. ¼ sec. 11, T. 63–4, the gabbro (No. 217) occurs and continues along the south shore most of the way to the stream that enters the lake in the S. E. ¼ of sec. 10. In the S. W. ¼ of N. W. ¼ sec. 11, just east of the line between secs. 10 and 11, there is an exposure of diabase (No. 218). The gabbro on the little point in the S. E. ¼ of sec. 10 is cut by a dike of fine diabase (No. 219); the dike runs a little west of north; it is three feet wide and was traced twenty feet. The gabbro at this point is represented by No. 220, which is exactly similar to that found much farther north.

A trip was made south to the corner between secs. 10, 11, 14, and 15 and then west along the line between secs. 14 and 15 for nearly half a mile; the line could be followed no farther, and so we went as near west as possible until two miles west of the above corner. Many rounded hills of gabbro were crossed,—in fact all the rock seen was gabbro except a small outcrop about three-fourths of a mile from the corner; this outcrop consisted of a fine-grained rock (No. 221) which, if it were a little more decayed, would resemble what has been termed "muscovado." One of the specimens collected (No. 222) is from a vein which contained large crystals of hornblende, an inch or more long. In some places there were small patches or seams of gabbro that contained considerable magnetite, as shown by No. 223, but in no place did the magnetite make up more than one-third of the rock. At one place, one and a half miles west of the corner, there was a thin scale, not much more than half an inch thick, of magnetite lying on the gabbro; this extended only about 20 feet; No. 224 is from this scale of magnetite. From the last place (one and a half miles west from the corner) Mr. Meeds went north for half a mile, and found nothing but gabbro. A section was also made south for half a mile; the gabbro was the only rock seen.

Gabbro continues along the north and west shores of the lake in sec. 10; it was examined in several places. There is a very small bay in the N. W. ¼ of N. E. ¼ sec. 10; on the east side of the entrance to this bay there is an exposure of gabbro sloping down to the water. The surface of the gabbro is spotted with small and irregular pieces of the fine red syenite (No. 225), and there are veins of this syenite in the gabbro; there is also a large piece of syenite, 10 by 20 feet. This large piece and the smaller pieces of syenite seem to lie on the gabbro; and this, together with the fact that the gabbro is cut by veins or dikes of the syenite, would indicate that *the syenite is of later date than the gabbro.* The top of the gabbro exposure is cut by an irregular dike, which at one end is three feet wide; it then widens out to twelve feet. The direction of the dike is nearly east and west, and it was traced forty feet. The syenite at this place is represented by No. 225, the dike rocks by No. 226, and the gabbro by No. 227. This is the first place that the writer has found the fine red syenite in contact with the gabbro. The two are seen in contact again at the northwest corner of this little bay; here the contact is vertical, and is a sharply defined line, but there is only a small (four feet wide) strip of syenite exposed.

Many outcrops of gabbro are seen along the west shore of the lake till we reach a small island in the N. E. ¼ of S. E. ¼ sec. 3. On the north side of this island the gabbro and the fine red syenite are again seen in contact; *here the gabbro lies on the syenite,* which is represented by No. 228. A bluff of rock about thirty

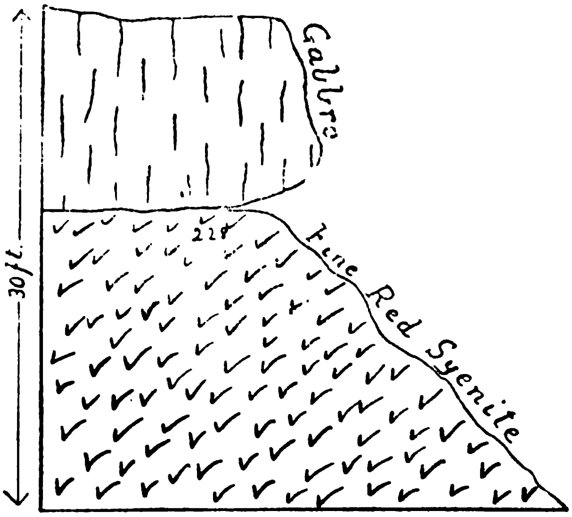


Fig. 4. Gabbro lying on fine red syenite, lake Ida Belle.

feet high is exposed; the upper part is composed of gabbro, which projects out beyond the syenite lying below. At the contact the gabbro has crumbled away, so the actual contact line could not be seen, but the two rocks were found within an inch of each other. There seems to be no change in either rock near the contact.

In the N. E. ¼ of S. E. ¼ and S. E. ¼ of N. E. ¼ sec. 3, T. 63-4, just north of the island mentioned above, there is a hill composed of a dark fine-grained rock (No. 229). This is cut through and through by numerous, irregular, branching veins of the fine red syenite (No. 230); these vary from two feet to half an inch in width, and even run out to needle-points. No. 229 seems to be a syenite, like the red syenite, but the hornblende makes up so large a part of it that the rock appears almost black. It is different from the dark rock seen in the syenite on the north side of Found lake. No. 231 shows Nos. 229 and 230 in contact; the contact is a distinct and sharply defined line, and in no place were the two rocks found to grade into each other.

The rest of the lake shore was examined; gabbro was found in many places, especially along the eastern shore. On the west shore, near the centre of sec. 2, T. 63–4, were two exposures of No. 229 cut as above described by fine red syenite similar to No. 228. At the extreme northeastern corner of the lake, in the S. W. ¼ of sec. 31, T. 64–3, the red syenite again occurs. At the portage (S. E. ¼ of sec. 35, T. 64–4) going north from lake Ida Belle the gabbro was cut by veins of fine red syenite (No. 232).

FROM LAKE IDA BELLE TO OGISHKE-MUNCIE LAKE.

Narrow lake. This is a narrow irregular lake in secs. 25, 26, 35, and 36 of T. 64–4; it is a mile and a half long (north and south), but not more than a quarter of a mile wide. It is 15 feet below lake Ida Belle. The shores are densely wooded, the timber being mostly spruce, birch and jack pine. The portage from lake Ida Belle is in the S. E. ¼ of sec. 35; it is well cut and only about an eighth of a mile in length. Gabbro occurs on the west shore in the N. E. ¼ of sec. 35. On the west shore (S. E. ¼ of N. E. ¼ sec. 26) near the north end of the lake is what seems to be a decayed condition of the gabbro (No. 233); this contains considerable biotite.

*Kiskadinna lake**. This lake is mostly in sec. 24, T. 64–4 and secs. 19 and 20, T. 64–3. It is 25 feet below Narrow lake. The shores are densely wooded. The northern arm, which is in the S. E. ¼ of sec. 13, T. 64–4 and the N. W. ¼ of sec. 19, T. 64–3, is shown on the plat as a separate lake, but it is only an arm of Kiskadinna lake. There are two short portages from Narrow lake to this lake along the stream that connects the two lakes. Not many rock exposures are to be seen along the shores of this lake; all those examined were gabbro. Gabbro also occurs on the south shore of the northern arm where the line between ranges 3 and 4 touches the shore.

Kiskadinna lake to Round lake. In the N. W. ¼ of S. E. ¼ sec. 13, T. 64–4 there is a short portage from Kiskadinna lake past a rapids in the stream† that flows from this lake through secs. 13, 11, 10, 3, and 2 of T. 64–4 into Round lake which is in the S. W. ¼ of sec. 35, T. 64–5. There are three rapids along this stream where short portages are made—in the N. W. ¼ sec. 13, S. W. ¼ Sec. 11, and N. W. ¼ sec. 2,—this last portage coming to Round lake. The stream is easily canoeable, being usually from 100 to 1,000 feet wide. The portages are well cut and seem to be used considerably in the winter time. The only rock seen along this stream was gabbro; this occurred in several places, as follows: near the centre of sec. 13, S. E. ¼ of sec. 11, on the portage in the S. W. ¼ of sec. 11, N. E. ¼ of sec. 10, S. W. ¼ of sec. 2, N. W. ¼ of sec. 2, and on the portage in the N. W. ¼ of sec. 2. Round lake is 60 feet below Kiskadinna lake.

---

* This name is taken from Heinze Brothers "Map of the Vermillion Iron Range."

† This stream finally enters Gunflint lake at its western end.

Draper lake. This is a somewhat circular lake in the W. ½ of sec. 34 and the E. ½ of sec. 33, T. 65–4. It is 35 feet above Round lake. A portage of about half a mile connects these two lakes; it leaves Round lake at its northwestern corner. The gabbro occurs in several places along this portage. There are also many fragments of quartzyte on the portage, but no rock was found in place; these are probably from what has been termed Pewabic quartzyte found a short distance north of here. On the western shore of the lake, in the N. E. ¼ of sec. 33, there is an exposure of a muscovado-like rock (No. 233½).

Draper lake to Flying Cloud lake. From Draper lake we went through six small lakes to Flying Cloud lake. This plat (T. 65–4) is very inaccurate, and the route we took and the position of the lakes could not be definitely determined. Below, the lakes have been numbered from one to six, and the location given as near as possible.

Lake No. 1:—Near the centre of sec. 33, T. 64–5. Forty feet above Draper lake.

Lake No. 2:—N. W. ¼ of sec. 33, T. 64–5, not shown on the plat. Same hight as lake No. 1.

Lake No. 3:—This is probably Charley lake, which is in the N. ½ of sec. 32, T. 65–4. Fifteen feet above lake No. 2.

Lake No. 4:—Centre of sec. 29, T. 65–4. Not shown on the plat. Forty feet above lake No. 4. On the west side of the portage (this portage runs nearly north) from lake No. 3 there is a bluff 25 feet high and over 100 feet long; the front of the bluff is perpendicular. At the base near the centre there is a fine gray syenite (No. 234), forming the first eight feet of and extending for 25 feet along the foot of the bluff. Directly over the syenite and lying on it is the gabbro (No. 235) which composes most of the bluff. The change from the gabbro to the syenite was abrupt, there being no transition. The contact line was not easily seen as the face of the bluff was covered with lichens, but on chipping off small pieces of the rock the syenite and gabbro were seen within an inch of each other. The syenite is very much finer than the Saganaga syenite found on the north shore of Gunflint lake. Just across the portage-trail from this bluff of syenite and gabbro there is one exposure of "muscovado" (No. 236) similar to No. 233½. A little island in the southern part of lake No. 4 is made up of a fine gabbro (No. 237) that seems to contain considerable olivine.

Lake No. 5:—E. ½ of sec. 30, T. 65–4. Not shown on the plat. This is a small lake, not more than a quarter of a mile across. Same hight as lake No. 4.

Lake No. 6:—S. W. ¼ of sec. 30, T. 65–4, and S. E. ¼ of sec. 25, T. 65–5. 25 feet below lake No. 5.

Flying Cloud lake:—This lake is about a mile in length, and lies in the S. ½ of S. ½ of sec. 25, and a small portion is in the N. W. ¼ of sec. 36, T. 65–5. 30 (?) feet below lake No. 6.

On the south shore near the east end of the lake (S. E. ¼ of S. E. ¼ sec. 25) there is a low ridge of dark, almost black, quartzyte running east and west. This quartzyte stands vertical, and the strike, as near as could be estimated without the needle, which is here much disturbed, is about east and west. The bedding is very plainly seen, especially on the weathered surfaces; this is caused by bands, which contain varying proportions of the two minerals of the rock,—quartz* and magnetite. The specimens collected (No. 238) fairly represent the rock, which is so rich in magnetite that it would make a fair iron ore. The principal exposure is in a vertical north facing wall, 12 feet high and 40 feet long, but several other smaller exposures are seen for 150 feet east of this. At the foot of the ridge is an outcrop of greenstone (No. 239). It seems as if the quartzyte overlies the greenstone, but this could not be positively determined (however, this is found to be the case about a mile west of this point). This quartzyte is the Pewabic quartzyte described in the 16th annual report, and the greenstone is probably the same as that mentioned in connection with the quartzyte.

From Flying Cloud lake we went southwest for about two miles along a stream—making four short portages—to Kakego lake. On the north side of this stream, a short distance west of the first portage from Flying Cloud lake (probably in the S. E. ¼ of S. E. ¼ sec. 26, T. 65–5), the Pewabic quartzyte again occurs; here it is fully as rich in iron as seen at any other place. This lake. The stream is easily canoeable, being usually from 100 to 1,000 feet wide. The portages are well cut and seem to be used considerably in the winter time. The only rock seen along this stream was gabbro; this occurred in several places, as follows: near the centre of sec. 13, S. E. ¼ of sec. 11, on the portage in the S. W. ¼ of sec. 11, N. E. ¼ of sec. 10, S. W. ¼ of sec. 2, N. W. ¼ of sec. 2, and on the portage in the N. W. ¼ of sec. 2. Round lake is 60 feet below Kiskadinna lake.

---

* It is quite probable that there is also olivine in the rock.

Draper lake. This is a somewhat circular lake in the W. ½ of sec. 34 and the E. ½ of sec. 33, T. 65–4. It is 35 feet above Round lake. A portage of about half a mile connects these two lakes; it leaves Round lake at its northwestern corner. The gabbro occurs in several places along this portage. There are also many fragments of quartzyte on the portage, but no rock was found in place; these are probably from what has been termed Pewabic quartzyte found a short distance north of here. On the western shore of the lake, in the N. E. ¼ of sec. 33, there is an exposure of a muscovado-like rock (No. 233¼).

Draper lake to Flying Cloud lake. From Draper lake we went through six small lakes to Flying Cloud lake. This plat (T. 65–4) is very inaccurate, and the route we took and the position of the lakes could not be definitely determined. Below, the lakes have been numbered from one to six, and the location given as near as possible.

Lake No. 1:—Near the centre of sec. 33, T. 64–5. Forty feet above Draper lake.

Lake No. 2:—N. W. ¼ of sec. 33, T. 64–5, not shown on the plat. Same hight as lake No. 1.

Lake No. 3:—This is probably Charley lake, which is in the N. ½ of sec. 32, T. 65–4. Fifteen feet above lake No. 2.

Lake No. 4:—Centre of sec. 29, T. 65–4. Not shown on the plat. Forty feet above lake No. 4. On the west side of the portage (this portage runs nearly north) from lake No. 3 there is a bluff 25 feet high and over 100 feet long; the front of the bluff is perpendicular. At the base near the centre there is a fine gray syenite (No. 234), forming the first eight feet of and extending for 25 feet along the foot of the bluff. Directly over the syenite and lying on it is the gabbro (No. 235) which composes most of the bluff. The change from the gabbro to the syenite was abrupt, there being no transition. The contact line was not easily seen as the face of the bluff was covered with lichens, but on chipping off small pieces of the rock the syenite and gabbro were seen within an inch of each other. The syenite is very much finer than the Saganaga syenite found on the north shore of Gunflint lake. Just across the portage-trail from this bluff of syenite and gabbro there is one exposure of "muscovado" (No. 236) similar to No. 233½. A little island in the southern part of lake No. 4 is made up of a fine gabbro (No. 237) that seems to contain considerable olivine.

Lake No. 5:—E. ½ of sec. 30, T. 65–4. Not shown on the plat. This is a small lake, not more than a quarter of a mile across. Same hight as lake No. 4.

Lake No. 6:—S. W. ¼ of sec. 30, T. 65–4, and S. E. ¼ of sec. 25, T. 65–5. 25 feet below lake No. 5.

Flying Cloud lake:—This lake is about a mile in length, and lies in the S. ½ of S. ½ of sec. 25, and a small portion is in the N. W. ¼ of sec. 36, T. 65–5. 30 (?) feet below lake No. 6.

On the south shore near the east end of the lake (S. E. ¼ of S. E. ¼ sec. 25) there is a low ridge of dark, almost black, quartzyte running east and west. This quartzyte stands vertical, and the strike, as near as could be estimated without the needle, which is here much disturbed, is about east and west. The bedding is very plainly seen, especially on the weathered surfaces; this is caused by bands, which contain varying proportions of the two minerals of the rock,—quartz* and magnetite. The specimens collected (No. 238) fairly represent the rock, which is so rich in magnetite that it would make a fair iron ore. The principal exposure is in a vertical north facing wall, 12 feet high and 40 feet long, but several other smaller exposures are seen for 150 feet east of this. At the foot of the ridge is an outcrop of greenstone (No. 239). It seems as if the quartzyte overlies the greenstone, but this could not be positively determined (however, this is found to be the case about a mile west of this point). This quartzyte is the Pewabic quartzyte described in the 16th annual report, and the greenstone is probably the same as that mentioned in connection with the quartzyte.

From Flying Cloud lake we went southwest for about two miles along a stream—making four short portages—to Kakego lake. On the north side of this stream, a short distance west of the first portage from Flying Cloud lake (probably in the S. E. ¼ of S. E. ¼ sec. 26, T. 65–5), the Pewabic quartzyte again occurs; here it is fully as rich in iron as seen at any other place. This is shown by No. 240. It dips south about 40°. Twelve feet north of this quartzyte is a low outcrop of greenstone (No. 241); this is much darker and heavier than No. 239 and apparently contains considerable iron. The position and dip of the quartzyte would bring it over the greenstone. The contact between the two rocks was covered by soil. On the south side of the stream is a ridge, 50 feet high, of the quartzyte dipping south about 50°. No. 242.

---

* It is quite probable that there is also olivine in the rock.

On the east end of the second portage from Flying Cloud lake the quartzyte is again seen; here it dips south 45°. On the west end of the portage the quartzyte is found lying on the greenstone (see Fig. 5). This is probably in the N. W. ¼ of N. E. ¼ sec. 35, T. 65–5. The contact is abrupt and there is no transition from one rock to the other. Both rocks seem to be unchanged near the contact, except that the greenstone is a little decayed. The Pewabic quartzyte, dipping south 45°, is shown by No. 243, which was taken within six inches of the contact. The greenstone is shown by No. 244; this seems to be similar to No. 239.

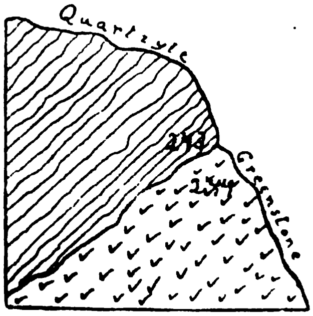


Fig. 5. *Pewabic quartzyte lying on greenstone, N. W. ¼ of N. E. ¼ sec. 35, T. 65–5.*

SHOO-FLY LAKE.*

This lake is in the S. E. ¼ of sec. 11 and the N. E. ¼ of sec. 14, T. 64–7. On the little point, in the N. E. ¼ of N. E. ¼ sec. 14, there is a fine-grained condition of the gabbro (No. 245), and on the east side of the lake near the southern end there is a precipitous cliff of the same rock rising 50 feet above the water,

---

*The following notes were taken on a trip from Knife lake through Kekequabic, Shoo-fly, Fraser, Thomas, Alice and Wilder lakes, thence along the Kawishiwi river to the S. E. ¼ of sec. 8, T. 62–9, and then through Gull lake to Mishiwishi lake.

From Shoo-fly lake a portage of a third of a mile runs south to a small lake, not shown on the plat, in the S. W. ¼ of sec. 13, T. 64–7. On the west side of this lake near the northern end there is an outcrop of gabbro (No. 246); this is finer than the ordinary gabbro. On the west side of the lake near the southern end is another outcrop of gabbro (No. 247) which seems to be a decayed condition of No. 246. From the southern end of this lake a portage runs south for about a third of a mile and reaches Fraser lake in the N. W. ¼ of N. W. ¼ sec. 24, T. 64–7.

FRASER LAKE.

Fraser lake is mostly in secs. 22, 23 and 24 of T. 64–7. On the north side of the lake in the S. E. ¼ of S. W. ¼ sec. 14, T. 64–7 there are several exposures of iron ore;* these were examined rather carefully. About 150 yards north of the shore, where it is cut by the line between secs. 14 and 23, is a small pit, four feet deep. At the bottom of this pit is found quite a rich olivinitic iron ore (No. 248); this disturbs the needle but slightly and seems to be mostly menaccanite rather than magnetite. On the north this comes in contact with a wall of rock (No. 249) composed of large crystals of hornblende (?) that is almost fibrous; in this there are parallel bands of iron ore (Nos. 250 and 251) which run east and west and dip south about 80°. No. 250 is similar to the ore in the pit, while No. 251 is distinctly a magnetic quartzyte and shows the bedding plainly. A few rods northeast of this pit, and at the top of the steep northward slope, is another exposure of olivinitic iron ore (No. 252); this appears similar to the ore in the pit, but affects the needle very strongly, thus probably being mostly magnetite. This mass of iron ore at its western edge comes into direct contact with a hornblende rock (No. 253) which is a less decayed condition of No. 249. The hornblende rock is here also in contact with a fine "muscovado" (No. 254) which shows a few large crystal faces of feldspar, half an inch or more in length. Very little of these two rocks was seen and their relation to each other was not determined. The contact line is irregular and there is no transition from one to the other, nor is there any sign of alteration in either rocks near the contact. A few small areas in this hornblende rock were quite rich in iron, as shown by Nos. 255 and 256, but the limits of these areas were rather sharply defined. The observations were made on a ridge which runs east and west; it was examined for 100 yards on each side of the above mentioned pit. The north side of the ridge is rather steep and at its foot occurs the muscovado, here represented by No. 257. As far as exposed the top of the ridge is composed of the hornblende rock (Nos. 249 and 253); this holds many masses and bands of magnetitic quartzyte. The bedding in the quartzyte is usually very distinct; in all the places examined it runs east and west, but within ten feet the dip varies from the vertical to about 45° south. The masses of iron ore where Nos. 248 and 252 were obtained contain very little quartz and show no evidence of bedding. The line of contact between the quartzyte and the surrounding rock is usually distinct and very irregular; there was no blending of the two rocks. No. 258* shows the quartzyte, and in the specimens numbered 259 the bedding is plainly seen. No. 260 shows the contact of the quartzyte and the surrounding rock.

---

*This is the place where an attempt was made to mine for gold several years ago.

In the N. W. ¼ of N. E. ¼ sec. 23, about a quarter of a mile west of the previously described locality, is a ridge running east and west; this is probably an eastward continuation of the ridge mentioned above. On the south side near the base of the ridge and about 50 feet from the lake a rather fine, decayed, gabbro-like rock (No. 261) occurs; this is exposed in several places; it has a rough bedded structure (the beds being from 6 to 12 inches thick) which is nearly horizontal. On the north side of the ridge and near its foot is a small exposure of iron ore (No. 262); it has a tendency to split along parallel plains which are vertical and run east and west. Within ten feet of this ore the quartzyte is seen. The ridge at this place is made of quartzyte which was followed eastward for 50 yards, where the ridge ends abruptly. The bedding is very nicely seen along the weathered surfaces; it is caused by bands of almost pure quartz alternation with bands rich in magnetite. Some of these bands are shown by Nos. 263, 264 and 265. Throughout the fifty yards that the quartzyte was followed, except in one small area where the beds had been broken and bent, the strike and dip were constant, the former being almost east and west, and the latter south 75°. At the eastern end of the ridge a band two feet wide, of a fine muscovado-like rock (No. 266) occurs interbedded with the quartzyte; this rock was traced for over 30 feet; it has a tendency to a rough cleavage which is parallel with the quartzyte bedding. On the south side of the ridge, but not within 30 feet of any quartzyte, is also found an outcrop of the iron ore (No. 267) which has weathered into thin parallel sheets conformable with the quartzyte.

---

*No. 268 was taken from the quartzyte near this; it is a bunch of the crystals of the hornblende rock, but they seem to be mostly magnetite.

The quartzyte described at these two localities on Fraser lake is decidedly like the Pewabic quartzyte. Evidently the gabbro, which covers this section of country, has been worn away and a much disturbed portion of the underlying quartzyte exposed. The quartzyte was not seen in contact with, nor in fact near any of the ordinary labradorite gabbro, but this gabbro has been seen on all sides of it at places usually less than a mile distant.

THOMAS LAKE.

This lake is in secs. 27, 28, 29, 32, 33 and 34 of T. 64–7, and secs. 5 and 6 of T. 63–7. There is some good white pine along the southern shore of the lake; several claim cabins were seen here.

The iron ore, shown on the map (in the 15th annual report) as occurring on the north side of the lake in secs. 27 and 28, was not found, although the locality was carefully examined. The only iron seen was a small amount of menaccanite in the gabbro (No. 269); this specimen was found about a quarter of a mile north of the lake in the N. E. ¼ of sec. 28.

On the north side of the mouth of the little bay, which is near the centre of the W. ½ of sec. 27, there is a bluff 40 feet high, of muscovado (No. 270) holding irregular blotches of a light colored feldspar.

On the lake shore in the N. E. ¼ of sec. 29, on a little point that is about half way between the meander corner on the line between secs. 28 and 29 and the stream that flows toward Ima lake, is a low outcrop of rock (No. 271) similar to the hornblende rock found at Fraser lake. Here were many angular fragments of quartzyte (similar to the Pewabic quartzyte); one specimen (No. 272) was taken to show how plainly the banding appears on a weathered surface. A few feet back from the shore is an outcrop, two feet high, of magnetic iron ore (No. 273);* this is composed of almost pure magnetite with a little olivine. This ore was not seen in contact with any other rock, but it contains a few of the crystals that make up the hornblende rock. No bedding could be seen. On farther search a low outcrop of quartzyte, similar to that seen at Fraser lake, was found about 50 yards from the shore. By pulling away the moss and soil this rock was exposed for twelve feet. It lies nearly horizontal, dipping south about 10°. Nos. 274 and 275 show this quartzyte. As the shore at this point is low and there is very little rock exposed, the relations of the hornblende rock, the iron ore and the quartzyte could not be determined.

---

* This is probably the ferruginous gabbro mentioned in the 15th annual report, page 360, but no hammer marks were seen here. (It was this which was intended to be represented on the map. N. H. W.)

LAKE ALICE.

From the extreme southwestern corner of Thomas lake a portage, of less than a quarter of a mile, leads southwest to Gabiskamak* lake, which is an irregular lake lying in sec. 6 of T. 63-7. The shores of this lake, except a small portion at the northern end, have been burnt and are now partially covered by bushes 8 to 10 feet high. There were many rock outcrops along the shores; all of those visited were gabbro, and the others appeared to be the same.

From the south end of Gabiskamak lake a portage of half a mile leads south to the arm of Wilder lake that extends into the S. E. ¼ of sec. 7, T. 63-7. Gabbro was seen in several places on the portage; also on the west shore of the arm of Wilder lake. The north shore of the Kawishiwi river was examined from Wilder lake to lake Alice; no rock was seen except gabbro and there were many exposures of this. Between these two lakes both shores of the river have been burnt and are now covered with small birches, poplars and jack pines.

Lake Alice lies mostly in secs. 9, 10, 15, 16 and 21 of T. 63-7. It is four feet above Wilder lake and is connected with it by two miles of river in which there is one fall; this is in the N. E. ¼ of N. W. ¼ sec. 20, T. 63-7. The Chippewa name for this lake is Pe-na sagiagan or Partridge lake. The island crossed by the line between secs. 9 and 16 has not been burnt; also the N. W. ¼ of S. E. ¼ sec. 15, where there is a claim cabin and some Norway pine. The rest of the shore has been burnt and is now covered with young birches, jack pines, and poplars. From the end of the bay in the N. W. ¼ of sec. 22 there is a portage leading east; there is also one, leading east, leaving the lake in the N. W. ¼ of S. E. ¼ sec. 10. From the extreme northern end of the lake a short portage leads to a small lake, on the south shore of which the gabbro is exposed. Lake Alice, and especially the eastern side, was rather carefully examined, stops being made about every 200 or 300 yards (the bay in the N. E. ¼ of sec 9 was not entered); no rock was found except the ordinary labradorite gabbro; this was seen in very many places; No. 277 is a sample from the S. E. ¼ of N. W. ¼ sec. 15. In one place on the east side of the long bay in sec. 15 the gabbro (No. 276) is of a decidedly pinkish color; the labradorite crystals have a pinkish tinge and there are blotches of a very soft, brick-red mineral, probably an oxide of iron. Search was made back from the shore for more of this pink gabbro, but none was found.

---

*This is the Chippewa name of the lake; I do not know its meaning.

LAKE ALICE TO MISHIWISHIWI LAKE.

The bay of Wilder lake which lies in sec. 13, T. 63-8, was not entered by the survey two years ago; and so it was examined on this trip; no rock was seen except the gabbro.

From Wilder lake the Kawishiwi river was followed to the little bay in the N. W. ¼ of S. E. ¼ sec. 3, T. 62-9; here a portage of about two miles was made southeast to Gull lake. There is no portage route through this way,—only a very poor trail which is used by the Indians in their winter trapping. On the way three ponds were crossed; one in the S. ½ of sec. 3, T. 62-9, one in the N. E. ¼ of sec. 9, and one on the line between secs. 9 and 16;—no rock exposures were seen on these ponds, but there were exposures of gabbro in the N. W. ¼ of sec. 10 and the N. W. ¼ of sec. 16.

Gull * lake is a narrow body of water extending northeast and southwest in sections 16, 17, 19 and 20 of T. 62-9. The shores are closely covered with spruce and jack pine. The west side of the lake was examined; all the rock seen was the ordinary gabbro. From the southwest corner of this lake a fair portage, over a mile in length, leads southwest and reaches Mishiwishiwi lake where the line between secs. 24 and 25, T. 62-10 crosses the shore. Gabbro occurs along this portage.

PINE ISLAND, VERMILION LAKE.

A section was made across Pine island, on the line between ranges 15 and 16, in order to examine a hill of jasper reported

---

*The Chippewa name is Gaiashk (Gi-äshk) sagaigan or Gull lake.

to be there. The writer crossed the island on this line and also went west from the line for a mile, near the centre of the island, but found no jasper hill, nor any indications of jasper. The rocks seen on the section across the island are given below.

At the north side of the island is a hill, rising 40 feet above the water; this is made of vertical, rather siliceous, sericitic schist (No. 284); the strike is E. 15° N. From this hill a swamp, where there are no rock exposures, extends for nearly one-fourth of a mile south of the corners of T. 62–15, 62–16, 63–15 and 63–16. At the south end of the swamp is a low (six feet high) ridge of sericitic schist (No. 285); strike E. 20° N., vertical. Just north of the quarter post there are three ridges running east and west. The first ridge is composed of a greenish rock, which on the north side of the ridge is quite schistose and somewhat sericitic (No. 286); strike E. 10° N., vertical; on the south side the rock is more massive and graywacke-like (No. 287). The second ridge is made of a rough sericitic schist (No. 288); strike nearly east and west, vertical. No. 289 is from the third ridge; it is harder, greenish, and perhaps somewhat chloritic. South of the quarter post, and about an eighth of a mile from the lake, the following rocks were seen; strike E. 15° N., vertical. No. 290, light gray argillaceous slate; Nos. 291, 292 and 293, coarser and rather sericitic conditions of the same; Nos.294and295, light gray arigllaceous slate. No. 296 shows a more siliceous condition of the slate. At the lake shore there are fine argillaceous slates* (No. 298); these vary from black to gray; the slaty structure and the black and gray bands are parallel; strike E. 15° N., and dip 80° to the north. No. 297 shows the gray slate a few feet from the shore.

III. SUMMARY.

No generalization or theories would here be in place, but it may, perhaps, be admissable for the writer to give a very brief summary statement of the bearing of some of the facts in the foregoing notes upon the general geology of the region traversed. The following remarks relate, more or less, to the great gabbro sheet, which covers so much of that part of Minnesota north of lake Superior.

The fine red syenite, or "red rock" of former reports, was seen in several places on lake Ida Belle in contact with the gabbro. In one place (see fig. 4) the gabbro was in contact with and was unquestionably overlying the syenite; but in other places veins and dyke-like forms of what certainly appears to be the same syenite cut through the gabbro. The syenite has the appearance of an eruptive rock, and the general impression left on one, by seeing the outcrops on this lake, is that the syenite is of more recent date than the gabbro. The two rocks are very distinct and in no place were seen to grade into each other; where they were seen together the contact was a well defined line.

---

*Mentioned in 15 An. Rep., p. 303; No. 921.

The syenite found on the gabbro at Winchell lake is not the same as that just mentioned.

The iron ore and magnetic quartzyte (of which the ore is a part) found at Fraser and Thomas lakes are undoubtedly disturbed portions of the Animike beds now included in the gabbro. It is probable that they have not been moved far from their original position, and that, consequently, at this place the gabbro sheet is of a comparatively small thickness. It seems that all the ore at this place is from the quartzyte and that that portion which is but slightly magnetic has become charged with titanium from the gabbro. In connection with this quartzyte is found a peculiar rock that is made up of coarse and almost fibrous crystals of what is probably hornblende. This rock, as far as the writer knows, has been found in this region nowhere except in connection with this quartzyte and then only when the quartzyte was close to or in contact with the gabbro. The quartzyte south of Birch lake, at Chub (Akeley) lake and at Thomas and Fraser lakes also shows this.

IV. LIST OF, AND NOTES ON, THE TYPICAL ROCKS OF EACH OF WHICH 25 SPECIMENS WERE COLLECTED.

These specimens are, in many cases, from the exact spot from which the original specimens were collected and described, the writer having visited many of these localities with Prof. Winchell on two of his trips through this region. Some of the specimens from localities, not before visited by the writer, may not always be exactly the same as the original specimens, but they are very nearly the same,—as near as could be found from the notes given him. Only brief descriptions of many localities were accessible in the field, as the 16th annual report had not then been printed.

After each number the place where the original description can be found, is given.*

No. 744, (84):—Ogishke-Muncie conglomerate from Camper's island, Ogishke-Muncie lake; S. E. ¼ of S. W. ¼ sec. 23, T. 65–6. The specimens were taken from the southwest corner of the island. They show the matrix of the conglomerate, with sometimes a few of the smaller pebbles. The specimens collected are coarser and not as green as the original No. 744. 10th An. Rep., p. 91.

No. 751:—Hornblende porphyry, S. E. ¼ of sec. 30, T. 65–6; Kekequabic lake. No specimens of this were collected, as the rock was not found in place by the writer. It is similar to No. 1059 (97), except that the ground mass is inclined to brownish, while No. 1059 is yellowish green. See No. 1059 10th An. Rep., p. 92.

No. 868, (278):—Green chloritic schist embracing fragments of jaspilyte, north of Cady house, Tower. This rock evidently grades into No. 908 (281). 15th An. Rep., p. 267–8.

No. 892, (279):—Rough, scarcely banded jasper, north wall Stone mine, Tower. Owing to changes in the walls of the mine, this rock was not seen 75 feet below the surface; the specimens collected were taken about 25 feet below the rock surface. 15th An. Rep., p. 256.

No. 903, (280):—Red jasper with darker bands of iron ore; Stone mine, Tower.

No. 908, (281):—Matrix of conglomerate occurring north of the Cady house, Tower. 15th An. Rep., p. 269.

No. 916, (282):—Breccia, now converted to hematite and a floury white mineral; Breitung mine, Tower. 15th An. Rep., p. 250.

No. 921, (283):—Black or purplish-black clay slate, S. W. ¼ of S. W. ¼ sec. 6, T. 62–15; south shore of Pine island, Vermilion lake, a few feet east of the line between ranges 15 and 16. See notes on Pine island in this report. 15th An. Rep., p. 303.

No. 950, (128):—Siliceous schist or bedded quartzyte from "Silver City," N. E. ¼ of sec. 32, T. 63–11. The specimens were obtained from the shore, forty feet nearer the rapids than the southern tunnel is. 15th An Rep., p. 329.

No. 954, (114):—Coarse gabbro, east side of Birch lake. The specimens were taken from the same exposure from which the original specimen came. In the description (16th An. Rep.) this locality is given as the N. W. ¼ of sec. 20, T. 61–11, and in the catalogue of rock samples as the N. W. ¼ of Sec. 17. Judging from distances to known points (this town has not been surveyed) the writer thinks that the N. W. ¼ of sec. 17 is the right place. 15th An. Rep., p. 332.

---

*These are the numbers given by Prof. Winchell in the 10th, 15th and 16th annual reports. The numbers in parentheses and all under 300 are those given by the writer.

No. 958, (121):—Breccia of mica-schist cemented by granite from the little point in the N. E. ¼ of S. E. ¼ sec. 21, T. 61–12, Birch lake. Where the mica-schist showed the schistose structure to the best advantage, the rock was too much decayed for good specimens. 15th An. Rep., p. 333.

No. 960:—See No. 1138.

No. 963, (123):—Fine-grained red syenite, resembling the "red rock" of Grand Marais, from the S. W. ¼ of S. W. ¼ sec. 24, T. 61–12, Birch lake. The specimens were collected just east of the line between secs. 23 and 24, and about 300 feet back from the lake shore. 15th An. Rep., p. 336.

No. 979, (111):—Fine syenite from the "Palisades," N. W. ¼ of S. W. ¼ sec. 4, T. 62–10. The specimens are from near the southern end of the "Palisades" and about 20 feet above the water. The rock varies some and has an almost gneissic structure. The specimens collected represent the prevailing variety; this grades into No. 112, which is gray, and into No. 113, which is coarser. 15th An. Rep., p. 342.

No. 989, (101):—Fine grained, slightly micaceous quartzose rock from the south shore of the Kawishiwi river in the N. W. ¼ of N. W. ¼ sec. 27, T. 63–10. 15th An. Rep., p. 352.

No. 991, (102):—Gray, red-weathering gneissic rock from an island in the N. W. ¼ of N. W. ¼ sec. 27, T. 63–10, Kawishiwi river. The southern part of the island is composed of this rock, but on the central and northern parts the rock has many darker hornblendic bands which show very plainly on the weathered surface (No. 103). One much darker hornblendic band, about a foot in width, was seen; this (No. 104) seemed to be distinct from the others, which graded into one another. No. 991 also showed banding on weathered surfaces. 15th An. Rep., p. 352.

No. 994, (105):—Reddish chloritic syenite; N. E. ¼ of N. W. ¼ sec. 27, T. 63–10; south shore of Kawishiwi river. This rock is hardly a red syenite like the original No. 994, but in places it is reddish,—see No. 107, which is similar to the original No. 994; not enough of this reddish rock could be found for the specimens. This rock (No. 105) seems to grade into No. 108 and

No. 109; the latter has some biotite and the exposures show a rather distinct bedding, while the exposures of No. 105 do not. Lenticular pieces of a greenish chloritic schist (No. 110) are found in a few places in No. 105. 15th An. Rep., p. 353.

No. 1044, (85):—Gneissic (syenitic?) rock, south shore of the little bay at the southeast side of Kekequabic lake, S. E. ¼ of S. W. ¼ sec. 2, T. 64–7. The specimens were taken from the only outcrop, on the south side of this bay, where hammer marks were seen. The rock contains many small dark masses, apparently chloritic, as shown by No. 85; none of these were over an inch in diameter. In a few places this dark mineral is collected into rather indistinct vein-like forms, but there is no marked contrast between these "veins" and the surrounding rock. 15th An. Rep., p. 361.

No. 1049, (87):—Biotite gabbro, somewhat pebbly, east side of sec. 4, T. 64–7, Kekequabic lake. The water was so high that the specimens could not be collected in the bay in the east side of sec. 4, so they were taken from the N. E. ¼ of the S. E. ¼ of sec. 4; here the rock seems to be the same as in the bay. The pebbly structure of the rock is shown only where it has been water worn. At this place the gabbro lies on some gray earthy slate. The slate was down at the water's edge and there was only a very small area of it, so not much could be determined concerning it. No abrupt contact could be seen between the two rocks; there was a transition, occupying perhaps two feet, from the gray earthy slate (No. 88), through Nos. 89 and 90, to the gabbro (No. 87). 15th An. Rep., p. 364.

No. 1050, (91):—Fine-grained gabbro from the top of the same bluff, as from which No. 1049 was taken. The specimens were taken about 35 feet above the water. N. E. ¼ of S. E. ¼ of sec. 4, T. 64–7, Kekequabic lake. 15th An. Rep., p. 364.

No. 1059, (97):—Hornblende porphyry from the north shore of Kekequabic lake, N. E. ¼ of sec. 36, T. 65–7. Within a few inches this rock varies much, the hornblende crystals becoming smaller and fewer in number and sometimes almost wanting, as shown by the small specimen (No. 97). The rock is very hard and tough and rings like iron when struck by the hammer; it frequently contains crystals of iron pyrites. See No. 751. 15th An. Rep., p. 367.

No. 1068, (70):—Doleryte, from N. E. ¼ of sec. 24, T. 65–6; about a quarter of a mile southeast from the shore of Ogishke-Muncie lake. This rock contains considerable of a pinkish mineral (probably calcite); this mineral also occurs in small veins or fissures in the rock, shown by No. 71. 15th An. Rep., p. 371; also, 16th An. Rep., p. 95–6.

No. 1073, (69):—Coarse-jointed massive rock, apparently igneous, mouth of Ogishke-Muncie creek, N. E. ¼ of S. E. ¼ sec. 26, T. 65–6; Ogishke-Muncie lake. This rock overlies the following, which see. In some places the rock has cherty spots, as shown in the smaller specimen (No. 69), probably pieces of the slate (No. 1074). 15th An. Rep., p. 372.

No. 1074, (68):—Fissile black slate, baked and closely jointed, mouth of Ogishke-Muncie creek, N. E. ¼ of S. E. ¼ sec. 26, T. 65–6; Ogishke-Muncie lake. No specimens could be obtained at the contact with the overflowing rock (see above, No. 1073), as here the slate was much broken; the specimens collected are from the point made by the creek and the lake shore, which point is but a few yards west of No. 1073. At this place the slate plainly dips 20° S. of E. at an angle of about 80°. No. 68A was obtained just below the contact, while No. 68 B is from a piece of the slate included in the overlying rock. The slate has, in places, a decidedly conchoidal fracture as shown by No. 68C. The weathered surfaces on the specimens marked 68 show an apparently sedimentary banding which is parallel with the slaty structure. 15th An. Rep., p. 372.

No. 1094, (86):—Gray porphyritic rock, representing an altered conglomerate, from the point which has the corners of secs. 29, 30, 31, and 32, T. 65–6; north shore of Kekequabic lake. The specimens were taken from the southeast side of the point, or in the N. W. ¼ of N. W. ¼ sec. 32, T. 65–6. No. 86 shows a small one of the greenish nodules or pebbles. 15th An. Rep., p. 368; 16th An. Rep., p. 100.

No. 1098, (96):—Conglomeritic chlorite schist, from the north shore of Kekequabic lake where it is crossed by the line between T. 65–6 and 65–7. The small amount of the rock left uncovered by the porphyry and its decayed condition made it rather difficult to get good specimens. 15th An. Rep., p. 367.

No. 1100, (93):—Reddish syenite, island in sec. 3, T. 64–7, Kekequabic lake. No. 1100 is described from the most westerly island in the lake, but this island, which is just east of the point in the S. W. ¼ of N. W. ¼ of sec. 3, is small and low and is made up of a condition of the green chlorite schist (No. 94); the small island, just northeast of the last, seems to have no rock in place, but along the shore are many fragments of feldspar porphyry

(No. 95). The specimens (No. 1100) were taken from a larger island in the S. E. ¼ of N. W. ¼ sec. 3, just west of Animike island. 15th An. Rep., p. 362.

No. 1109, (100):—Felsitic schist, from the portage from Fall lake to Newton lake, S. W. ¼ of sec. 3, T. 63–11. The specimens were collected from the south, or Fall lake, end of the portage. 15th An. Rep., p. 356.

No. 1128, (129):—"Gabbro" cut by intrusive syenite; N. W. ¼ of S. E. ¼ sec. 6, T. 62–11, White Iron lake. See No. 1129, 15th An. Rep., p. 331.

No. 1129, (130):—Intrusive granite (syenite), N. W. ¼ of S. E. ¼ of sec. 6, T. 62–11, White Iron lake. Nos. 1128 and 1129 are from the place from which Dr. Wadsworth took the original specimens. The "gabbro" is not similar to the ordinary labradorite gabbro; it is perhaps a biotitic diabase. No. 131 is the syenite taken from a dike in the diabase. No. 1129 (130) is, I think, a fair sample of the syenite found about White Iron lake. 15th An. Rep., p. 331.

No. 1132, (127):—Black hornblende gneiss, east shore of White Iron lake, just south of the line between secs. 6 and 7 of T. 62–11. A set of specimens could not be obtained, as the gneiss only occurred in small masses in the syenite and here the surface was worn smooth by glaciation. No. 127 shows the contact between the gneiss and the syenite. 15th An. Rep., p. 331.

No. 1134, (124):—Micaceous "gabbro," or rather biotite hornblende schist, cut by veins of granite (syenite); N. W. ¼ of S. E. ¼ sec. 12, T. 62–12, east side of White Iron lake. The specimens were collected from the place where Dr. Wadsworth obtained the original ones. About 70 yards west of this place is the outcrop described by Dr. Alex. Winchell in the 15th annual report (see p. 77, halt 211). Here the hornblende schist is represented by No. 125, and the granite by No. 126. These two outcrops are connected by a ridge, in which the rock is not exposed, but the schist found at the east end (No. 124) is probably the same as that at the other end (No. 125). 15th An. Rep., p. 331.

No. 1137, (122):—Fine-grained gabbro, looking like diabase, from a point a short distance west of the line between secs. 24 and 25, T. 62–12; north shore of Birch lake. This seems to be a finer-grained condition of the ordinary labradorite gabbro. The specimens were obtained from the west side of the little bay in the S. E. ¼ of S. W. ¼ sec. 24. 15th An. Rep., p. 332.

No. 1138. Ferruginous olivine rock, about 15 rods from the shore; S. E. ¼ of S. W. ¼ sec. 24, T. 62–12; Birch lake. No specimens of this were collected, as a set of 25 (No. 960) was collected in 1886. It is a part of the great quartzyte formation (Animike) lying along the southern side of the Giant's range. 15th An. Rep., pp. 332 and 335.

No. 1278, (8):— Kewatin schist, mouth of the creek, east end of the long bay, north side of Gunflint lake. This is the most eastern exposure of the Kewatin on Gunflint lake. The rock at the shore was so cracked and broken that only four specimens were collected; these are marked 1,278A (8A). The rest of the specimens were taken from a low outcrop about 10 rods back from the shore; the schist here is similar to that at the shore, but is not so much decayed and is apparently more siliceous. 16th An. Rep., p. 67.

No. 1282, (9):—Gray gneissoid rock, slightly porphyritic; shore of the long bay, north side of Gunflint lake. The specimens collected do not answer exactly to the description, but they are a part of the same rocks. 16th An. Rep., p. 68.

No. 1283, (10):— Porphyrel; bluff north shore of Gunflint lake. The specimens were taken from a vertical cliff on the lake shore, about three-fourths of a mile west of the east end of the long bay. 16th An. Rep., p. 68.

No. 1312, (60):—Fine-grained trap, from the west side of the narrows of Gunflint lake; S. E. ¼ of N. W. ¼ of sec. 19, T. 65–3. In places this trap holds crystals of feldspar which sometimes are an inch long.

No. 1316, (46):—Syenitic gneiss from the north side of Blackfly bay, Gunflint lake. 16th An. Rep., p. 73.

No. 1318, (61):—Diabase dike in the syenite, first falls of Gunflint river, north of Gunflint lake. See this report under Gunflint lake.

No. 1340, (43):—Purplish-gray, vitreous quartzyte (Pewabic quartzyte), ⅛ mile west of the ore pit, Chub lake; N. E. ¼ of sec. 29, T. 65–4. 16th An. Rep., p. 85.

No. 1371, (72):—"Marble" from east side of Ogishke-Muncie lake; N. E. ¼ of sec. 24, T. 65–6. The place where the specimens were collected is probably where the section (p. 371, 15th An. Rep.) was made. No. 73 shows a softer, more schistose portion of No. 72. No. 74 are some of the angular pieces included in No. 72. No. 75 shows a soft greenish (probably talc) mineral found in the "marble" (No. 72). 16th An. Rep., pp. 95 and 96; also, under No. 1069, 15th An. Rep., p. 371.

No. 1409, (92):—Chloritic schist from the small island near the north shore and just west of the narrows of Kekequabic lake. This island is in the N. W. ¼ of N. E. ¼ sec. 36, T. 65–7; there is a much smaller island just east of it and also one north of it. 16th An. Rep., p. 102.

No. 1428, (98);—Dark siliceous slate, from the E. ½ of N. E. ¼ sec. 28, T. 65–7; Knife lake. This slate varies from grayish to black; the specimens collected are gray, as this colored rock made up most of the point. 16th An. Rep., p. 109.

No. 1436, (99);—Micaceo-syenitic gneiss, from Opinin island, Basswood lake. This island is in sec. 10 (probably N. E. ¼ of S. W. ¼), T. 64–10. 16th An. Rep., p. 110.

Twenty-five specimens of the *conglomeritic syenite* from Saganaga lake were also collected. The writer numbered these 66. No. 67 shows the syenite. This rock is described by Dr. Alex. Winchell in the 16th An. Rep., pp. 219–222, and p. 334; also in the American Geologist, vol. III, No. 3, p. 153.

V. BAROMETRICAL ELEVATIONS.

On the trip from Gunflint lake south to Brulé lake and north to Ogishke-Muncie lake the elevation of each lake was noted from readings of an aneroid barometer. The following table gives the elevation of each lake above lake Superior and also above the sea level. The elevation of Gunflint lake (the starting point) above lake Superior,—1,052 feet,—is taken from the 9th An. Rep., p. 81. The highest water noted is Lost lake which is 1,427 feet above lake Superior, or 2,029 feet above the sea.

	Feet above lake Superior.	Feet above the sea.
Gunflint lake	1052	1654
Loon lake (195 ft. above Gunflint lake),	1247	1849
Mayhew lake (110 feet above Loon lake),	1357	1859
Iron lake (same hight as Mayhew lake),	1357	1859
Portage lake (25 ft. above Iron lake),	1382	1984
Poplar lake (20 ft. below Portage lake),	1362	1964
Straight lake (25 ft. below Poplar lake),	1337	1939
Caribou lake (10 ft. below Straight lake),	1327	1929
Meed's lake (10 ft. above Caribou lake),	1337	1939
North Brulé lake (20 ft. below Caribou lake),	1307	1909
Stray lake (30 ft above North Brulé lake),	1337	1937
Gaskanas lake (15 ft. above Stray lake),	1352	1954
Winchell lake (30 ft. above Gaskanas lake),	1382	1984
Sham lake (15 ft. above Winchell lake),	1397	1999

	Feet above lake Superior.	Feet above the sea.
Lost lake (30 ft. above Sham lake),	1427	2029
Brulé lake (75 ft. below Lost lake),	1352	1954
Lake Georgia (6 ft. below Brulé lake),	1346	1948
Surveyor's lake (1 ft. above lake Georgia),	1347	1949
Found lake (same hight as Surveyor's lake),	1347	1949
Lake Ida Belle (30 ft. below Found lake),	1317	1919
Narrow lake (15 ft. below lake Ida Belle),	1302	1904
Kiskadinna lake (25 ft. below Narrow lake),	1277	1879
Round lake (60 ft below Kiskadinna lake),	1217	1819
Draper lake (35 ft. above Round lake),	1252	1854
Lake No. 1 (40 ft. above Draper lake),	1292	1894
Lake No. 2 (same hight as lake No. 1),	1292	1894
Lake No. 3 (15 ft. above lake No. 2),	1307	1909
Lake No. 4 (40 ft. above lake No. 3),	1347	1949
Lake No. 5 (same hight as lake No. 4),	1347	1949
Lake No. 6 (25 ft. below lake No. 5),	1322	1944
Flying Cloud lake (30 ft. below lake No. 6),	1292	1894
Kakego lake (65 ft. below Flying Cloud lake),	1227	1829
Clothes Pin lake (60 ft. below Kakego lake),	1167	1769
Gabemichigama lake (20 ft. below Clothes Pin lake),	1147	1749
Agamok lake (3 ft. below Gabemichigama lake),	1144	1746
Fox lake (30 ft. below Agamok lake),	1114	1716
Ogishke-Muncie lake (60 ft. below Fox lake),	1054	[*]1656
Wilder lake,	1102	[‡]1704
Lake Alice (4 ft. above Wilder lake),	1106	1708

VI. CATALOGUE OF ROCK SAMPLES TO ILLUSTRATE THE FOREGOING NOTES; COLLECTED BY ULY. S. GRANT DURING THE SUMMER OF 1888.

Most of these rock samples are of museum size; and in many cases more than one specimen was collected, to represent a certain number. This is especially true of the iron ores, of each of which several pieces were taken for analysis. The samples have been deposited in the rooms of the survey. They are numbered from 1 up to 298, inclusive; the figures are green,—paris green and shellac dissolved in alcohol being used; after each number the letter G is placed.

Nos. 132–146, inclusive, were placed on an island which was soon after overrun by a fire, and all the labels destroyed and the specimens discolored. These specimens have not been preserved:

---

[*] From figures in the 9th An. Rep., p. 84, Ogishke-Muncie lake is 1,611 ft. above the sea; and from the 15th An. Rep., p. 384, it is 1,507 ft. above the sea.

[‡] 15th An. Rep., p. 384.

1. Magnetic iron slate and jasper, N. ½ of sec. 33, T. 66–6; Ottertrack lake; 80 rods south of the lake shore. P. 151.

2. Same as No. 1. P. 151.

3. Magnetic iron slate and jasper, N. E. ¼ of N. W. ¼ sec. 27, T. 66–6 (if the U. S. sections were extended northward); north shore of Ottertrack lake. P. 151.

4. Graywacke-like rock north shore of Ottertrack lake. just west of No. 3. P. 151.

5. Graywacke-like rock, north shore of Ottertrack lake, just east of No. 3. P. 151.

6. Coarse syenite, small island in the S. E. ¼ of S. E. ¼ sec. 13, T. 65–4; Gunflint lake. P. 152.

7. Hornblende schist in syenite; same locality. P. 152.

8. Sericitic schist, at the shore near the east end of the long bay on the north side of Gunflint lake. Same as No. 1278 (N. H. W.). P. 199.

8A. Same as No. 8, but apparently more siliceous. P. 199.

9. Gray gneissic rock, almost porphyrel; north shore of the long bay on the north side of Gunflint lake. Same as No. 1282 (N. H. W.). P 199.

10. Porphyrel, on the shore about three-fourths of a mile west of the east end of the long bay on the north side of Gunflint lake. Same as No. 1283 (N. H. W.). P. 199.

11. Sericitic schist, north shore of Gunflint lake; section I. P. 152.

12. Earthy schist, north of Gunflint lake; section I. P. 153.

13. Fine porphyrelloid rock, north of Gunflint lake; section I. P. 153.

14. A coarser condition of 13, north of Gunflint lake; section I. P 153.

15. A finer condition of 13, north of Gunflint lake; section I. P. 153.

16. Black slate, north of Gunflint lake; section I. P 153.

17. Trap rock, north of Gunflint lake; section I. P 153.

18. Fine trap from outer edge of dike, north of Gunflint lake; section I. P 153.

19. Trap from centre of same dike, north of Gunflint lake; section I. P 153.

20. Sericitic schist, north of Gunflint lake; section I. P 153.

21. Black slate, north of Gunflint lake; section I. P 153.

22. Fine gabbro, north of Gunflint lake; section I. P. 153.

23. Black slate, north of Gunflint lake; section I. P. 153.

24. Porphyrel, north of Gunflint lake; section I. P. 154.

25. Gray, somewhat micaceous schist; north of Gunflint lake; section I. P. 154.

26. Hornblende schist, north of Gunflint lake; section I. P. 154.

27. Hornblende schist, north of Gunflint lake; section I. P. 154.

28. Mica-schist, north of Gunflint lake; section I. P. 154.

29. Feldspathic schist, north of Gunflint lake; section I. P. 154.

30. Hornblende schist, north of Gunflint lake; section I. P. 154.

31. Hornblende schist, north of Gunflint lake; section I. P. 154.

32. Mica-schist, north of Gunflint lake; section I. P. 154.

33. Hornblende schist, north of Gunflint lake; section I. P. 154.

34. Syenitic gneiss, north of Gunflint lake; section II. P. 155.

35. Hornblende schist inclosed in gneiss, north of Gunflint lake; section II. P. 156.

36. Trap from dike in gneiss, north of Gunflint lake; section II. P. 156.

37. Magnetitic portion of this dike, north of Gunflint lake; section II. P. 156.

38. Gray earthy slate, north of Gunflint lake; section II. P. 157.

39. Porphyrel, north of Gunflint lake; section II. P. 157.

40. Schistose dike rock, north of Gunflint lake; section II. P. 157.

41. Finer portion of No. 40, north of Gunflint lake; section II. P. 157.

42. Porphyrel inclosed in dike, north of Gunflint lake; section II. P. 157.

43. Purplish-gray, vitreous quartzyte (Pewabic quartzyte); N. E. ¼ of sec. 29, T. 65–4, Chub lake. Same as No. 1340 (N. H. W.). P. 199.

44. Magnetic iron ore from the pit at Chub lake, N. E. ¼ of Sec. 29, T. 65–4. P. 160.

45. Quartzyte core from drill; Chub lake, N. E. ¼ of sec. 29, T. 65–4. P. 160.

46. Syenitic gneiss from the north side of Blackfly bay, Gunflint lake. Same as No. 1316 (N. H. W.). P. 199.

47. Gray, red-weathering schist, north shore of Gunflint lake; section III. P. 157.

48. Black flinty slate, north of Gunflint lake; section III. P. 157.

49. Sericitic schist, north of Gunflint lake; section III. P. 157.

50. Gabbro, north of Gunflint lake; section III. P. 157.

51. Hornblende-feldspar schist, north of Gunflint lake; section III. P. 158.

52. Hornblende schist, north of Gunflint lake; section III. P. 158.

53. Mica-schist, north of Gunflint lake; section III. P. 158.

54. Hornblende schist, north of Gunflint lake; section III. P. 158.

55. Very coarsely-crystalline hornblende schist, north of Gunflint lake; section III. P. 158.

56. Same as 55, north of Gunflint lake; section III. P. 158.

57. Reddish syenite, north of Gunflint lake; section III. P. 158.

58. Syenitic gneiss, north of Gunflint lake; section III. P. 158.

58A. Same as 58, but showing the gneissic structure better; north of Gunflint lake; section III. P. 158.

59. Syenitic gneiss, north of Gunflint lake; section III. P. 158.

60. Fine-grained trap, from the west side of the narrows of Gunflint lake; S. E. ¼ of N. W. ¼ sec. 19, T. 65–3. Same as No. 1312 (N. H. W.). P. 199.

61. Diabase from dike in syenite, first falls of Gunflint river north of Gunflint lake. Same as No. 1318 (N. H. W.). P. 160.

61A. Fine condition of No. 61. P. 160.

62. Syenitic gneiss, first falls of Gunflint river north of Gunflint lake. P. 160.

63. A condition of No. 61. P. 161.

64. A condition of No. 61, showing pitted surface. P. 161.

65. Hornblende schist in No. 62; first falls of Gunflint river north of Gunflint lake. P. 161.

66. Conglomeritic syenite from Saganaga lake. P. 200.

67. Syenite, Saganaga lake. P. 200.

68. Black slate, mouth of Ogishke-Muncie creek, N. E. ¼ of S. E. ¼ sec. 26, T. 65–6; Ogishke-Muncie lake. Same as No. 1074 (N. H. W.). P. 197.

68A. Broken condition of No. 68. P. 197.

68B. Portion of No. 68 included in No. 69. P. 197.

68C. Showing conchoidal fracture of No. 68. P. 197.

69. Coarse-jointed massive rock, apparently igneous, mouth of Ogishke-Muncie creek, N. E. ¼ of S. E. ¼ sec. 26, T. 65–6; Ogishke-Muncie lake. Same as No. 1073 (N. H. W.). P. 197.

70. Doleryte, about a quarter of a mile southeast from the shore of Ogishke-Muncie lake; N. E. ¼ of sec. 24, T. 65–6. Same as No. 1068 (N. H. W.). P. 196.

71. Calcite from veins in No. 70.

72. "Marble" from east side of Ogishke-Muncie lake; N. E. ¼ of sec. 24, T. 65–6. Same as No. 1371 (N. H. W.). P. 199.

73. Softer and more schistose portion of No. 72. P. 199.

74. Angular siliceous pieces in No 72. P. 199.

75. Portion of No. 72 showing a soft greenish mineral.

76. Gray quartzyte, S. E. ¼ of N. E. ¼ sec. 24, T. 65–6; Ogishke-Muncie lake. P. 161.

77. Black slate, S. E. ¼ of N. E. ¼ sec. 24, T. 65–6; Ogishke-Muncie lake. P. 161.

78. Siliceous band in No. 76. P. 162.

79. Transition rock from No. 78 to No. 82. P. 162.

80. Transition rock from No. 78 to No. 82. P. 162.

81. Transition rock from No. 78 to No. 82. P. 162.

82. Rock composed mostly of calcareous or dolomitic matter; S. E. ¼ of N. E. ¼ sec. 24, T. 65–6; Ogishke-Muncie lake. P. 162.

83. Part of Ogishke-Muncie conglomerate; S. E. ¼ of N. E. ¼ sec. 24, T. 65–6; Ogishke-Muncie lake. P. 162.

84. Matrix of Ogishke-Muncie conglomerate; from Camper's island, S. E. ¼ of S. W. ¼ sec. 23, T. 65–6; Ogishke-Muncie lake. Same as No. 744 (N. H. W.). P. 194.

85. Gneissic (syenitic?) rock, south shore of the little bay at the southeast corner of Kekequabic lake; S. E. ¼ of S. W. ¼ sec. 2, T. 64–7. Same as No. 1044 (N. H. W.). P. 196.

86. Gray porphyritic rock, from the point which has the corners of secs. 29, 30, 31, and 32, T. 65–6; Kekequabic lake. Same as No. 1094 (N. H. W.). P. 197.

87. Biotite gabbro, N. E. ¼ of S. E. ¼ sec. 4, T. 64–7; Kekequabic lake. Same as 1049 (N. H. W.). P. 196.

88. Gray earthy slate, N. E. ¼ of S. E. ¼ sec. 4, T. 64–7; Kekequabic lake. P. 196.

89. Transition from the slate (No. 88) to the gabbro (No. 87). P. 196.

90. Transition from the slate (No. 88) to the gabbro (No. 87). P. 196.

91. Fine-grained gabbro, from the top of the bluff from which No. 87 was taken; N. E. ¼ of S. E. ¼ sec. 4, T. 64–7; Kekequabic lake. Same as No. 1050 (N. H. W.). P. 196.

92. Chlorite schist, N. W. ¼ of N. E. ¼ sec. 36, T. 65–7; Kekequabic lake. Same as No. 1409 (N. H. W.). P. 168.

93. Reddish syenite, from an island in Kekequabic lake; S. E. ¼ of N. W. ¼ sec. 3, T. 64–7. Same as No. 1100 (N. H. W.). P. 197.

94. A condition of the green chlorite schist, from island in the S. W. ¼ of N. W. ¼ sec. 3, T. 64–7; Kekequabic lake. P. 197.

95. Feldspar porphyry, from an island just northeast of the last; S. W. ¼ of N. W. ¼ sec. 3, T. 64–7; Kekequabic lake. P. 198.

96. Conglomeritic chlorite schist, from the north shore of Kekequabic lake where it is crossed by the line between T. 65–6 and T. 65–7. Same as No. 1098 (N. H. W.). P. 197.

97. Hornblende porphyry, from the north shore of Kekequabic lake; N. E. ¼ of sec. 36, T. 65–7. Same as No. 1059 (N. H. W.). P. 196.

98. Gray siliceous slate, from Knife lake; E. ½ of N. E. ¼ sec. 28, T. 65–7. Same as No. 1428 (N. H. W.). P. 200.

99. Micaceo-syenitic gneiss, from Opinin island, Basswood lake; sec. 10, T. 64–10. Same as No. 1436 (N. H. W.). P. 200.

100. Felsitic schist, from the south end of the portage from Fall lake to Newton lake; S. W. ¼ of sec. 3, T. 63–11. Same as No. 1109 (N. H. W.). P. 198.

101. Fine grained, slightly micaceous, quartzose rock; south shore of Kawishiwi river; N. W. ¼ of N. W. ¼ sec. 27, T. 63–10. Same as No. 989 (N. H. W.). P. 195.

102. Gray, red-weathering, gneissic rock, from an island in the N. W. ¼ of N. W. ¼ sec. 27, T. 63–10; Kawishiwi river. Same as No. 991 (N. H. W.). P. 195.

103. Hornblendic band in No. 102. P. 195.

104. Hornblendic band in No. 102. P. 195.

105. Reddish chloritic rock, N. E. ¼ of N. W. ¼ sec. 27, T. 63–10; south shore of Kawishiwi river. P. 195.

106. Hornblendic gneiss, N. E. ¼ of sec. 27, T. 63–10; south shore of Kawishiwi river. P. 195.

107. Reddish chloritic syenite, N. E. ¼ of N. W. ¼ sec. 27, T.

63-10; south shore of Kawishiwi river. Same as No. 994 (N. H. W.). P. 195.

108. Quartzose schist, grading into No. 105; same locality. P. 195.

109. Quartzose schist, with some biotite; same locality. P. 196.

110. Chloritic schist in No. 105; same locality. P. 196.

111. Fine syenite, from the "Palisades;" N. W. ¼ of S.W. ¼ sec. 4, T. 62-10. Same as No. 979 (N. H. W.). P. 195.

112. Fine grayish syenite, a condition of No. 111; same locality. P. 195.

113. Fine reddish syenite, a condition of 111; same locality. P. 195.

114. Coarse gabbro, east side of Birch lake, N. W. ¼ of sec. 17, T. 61-11. Same as No. 954 (N. H. W.). P. 194.

115. Magnetitic quartzyte, S. W. ¼ of sec. 9, T. 60-12; south of Birch lake. P. 163.

116. Magnetitic quartzyte, N. W. ¼ of sec. 10, T. 60-12; south of Birch lake. P. 163.

117. Biotitic gabbro, S. W. ¼ of sec. 10, T. 60-12; south of Birch lake. P. 162.

118. Same as No. 117, but showing dark bands. Same locality. P. 162.

118A. Same as 118, but from a loose piece. P. 162.

119. Gabbro, N. ½ of sec. 15, T. 60-12; south of Birch lake. P. 162.

120. Gabbro, N. E. ¼ of sec. 15, T. 60-12; south of Birch lake. P. 163.

121. Breccia of mica-schist cemented by granite, from the little point in the N. E. ¼ of S. E. ¼ sec. 21, T. 61-12; Birch lake. Same as No. 958 (N. H. W.). P. 195.

122. Fine-grained gabbro, from the west side of the little bay in the S. E. ¼ of S. W. ¼ sec. 24, T. 62-12; Birch lake. Same as No. 1137 (N. H. W.). P. 198.

123. Fine-grained red syenite, from the S. W. ¼ of S. W. ¼ sec. 24, T. 61-12; just east of the line between secs. 23 and 24, and 300 feet north from the shore of Birch lake. Same as No. 963 (N. H. W.). P. 195.

124. Biotite hornblende schist, N. W. ¼ of S. E. ¼ sec. 12, T. 62-12; east side of White Iron lake. Same as No. 1134 (N. H. W.). P. 198.

125. Biotite hornblende schist, N. W. ¼ of S. E. ¼ sec. 12, T. 62-12; east side of White Iron lake; 70 yards west of No. 124. P. 198.

126. Granite cutting No. 125; same locality. P. 198.

127. Black hornblende gneiss, just south of the line between secs. 6 and 7, T. 62–11; east shore of White Iron lake. This specimen shows the contact between the syenite and hornblende gneiss. Same as No. 1132 (N. H. W.). P. 198.

128. Siliceous schist, from "Silver City;" N. E. ¼ of sec. 32, T. 63–11. Same as No. 950 (N. H. W.). P. 194.

129. Biotitic diabase (?) cut by intrusive syenite, N. W. ¼ of S. E. ¼ sec. 6, T. 62–11, White Iron lake. Same as No. 1128 (N. H. W.). P. 198.

130. Syenite cutting No. 129; same locality. Same as No. 1129 (N. H. W.). P. 198.

131. Syenite taken from a dike in No. 129; same locality. P. 198.

132. Gabbro, north side of the little bay in the S. W. ¼ of S. E. ¼ sec. 15, T. 63–9; Kawishiwi river. P. 163.

133. Magnetitic iron ore in the gabbro, S. E. ¼ of sec. 15, T. 63–9. P. 163.

134. Muscovado, S. E. ¼ of N. E. ¼ sec. 15, T. 63–9; 60 yards northwest of the quarter post between secs. 14 and 15. P. 163.

135. Magnetitic iron ore; same locality as No. 134. P. 163.

136. Gabbro, showing gneissic structure; N. W. ¼ of sec. 5, T. 61–9; hill on east bank of stream. P. 164.

137. Gabbro, showing banding in No. 138; S. W. ¼ of sec. 5, T. 61–9; hill on west bank of stream. P. 165.

138. Gabbro, from same locality as No. 137. P. 165.

139. Red syenitic gneiss; S. ½ of sec. 32, T. 63–10; from a small island near the southern shore of the lake. P. 165.

140. Red syenite; S. ½ of sec. 32, T. 63–10; from a small island just north of the island where No. 139 was found. P. 165.

141. Syenite, with large crystals of hornblende; west side of the little bay in the N. W. ¼ of N. W. ¼ sec. 32, T. 63–10. P. 165.

142. Light gray gneiss; at the portage in the N. E. ¼ of N. W. ¼ sec 31, T. 63–10. P. 165.

143. Hornblende schist(?) in No. 142; same locality. P. 165.

144. Dark hornblende rock, from the southern shore of the lake; S. ½ of sec. 32, T. 63–10. P. 166.

145. Transition from No. 144 to the syenite like No. 140; same locality as No. 144. P. 166.

146. To illustrate the same transition as No. 145; same locality. P. 166.

147. Coarse gabbro; west side of the little bay in the S. W. ¼ of N. W. ¼ sec. 35, T. 62–8; lake Isabelle. P. 166.

148. Granulyte vein in the gabbro; a few rods north of No. 147. P. 166.

149. Very coarse gabbro; from cliff on the west side of the larger bay in the N. W. ¼ of sec. 35, T. 62–8; lake Isabelle. P. 166.

150. Trap rock, S. W. ¼ of N. E. ¼ sec. 35, T. 62–8; lake Isabelle. P. 166.

151. Coarser condition of No. 150; same locality. P. 166.

152. Coarser decayed condition of No. 150; same locality, but a few rods back from the shore. P. 166.

153. Coarser condition of No. 150; same locality as No. 152. P. 166.

154. Condition of No. 150, containing patches of biotite; on the shore, a little north of No. 150. P. 166.

155. A decayed condition of No. 154; same locality. P. 166.

156. A coarser condition of No. 154 and No. 155; same locality. P. 166.

157. Same trap, near contact with the gabbro; N. ½ of N. E. ¼ sec. 35, T. 62-8, lake Isabelle; on the shore, a few steps north of No. 156. P. 167.

158. Fine diabase from dike, N. E. ¼ of N. E. ¼ sec. 35, T. 62–8; lake Isabelle. P. 167.

159. Diabase from dike, S. W. ¼ of sec. 30, T. 62–7; lake Isabelle. P. 167.

160. Finer diabase from edge of the same dike from which No. 159 was taken. P. 167.

161. Fine diabase from dike, W. ½ of sec. 31, T. 62–7; lake Isabelle. P. 167.

162. Very coarse gabbro, north shore of Bellissima lake; probably from sec. 27, T. 61–7. P. 167.

163. Gray feldspathic rock, S. W. ¼ of sec. 21, T. 60–6; Pine lake. P. 163.

163A. Portion of No. 163 showing dark siliceous fragment; same locality as No. 163. P. 168.

163B. Transition from No. 163 to No. 164; same locality. P. 168.

164. Granulyte, S. W. ¼ of sec. 21, T. 60–6; Pine lake. P. 168.

164A. A darker and more siliceous condition of No. 164; same locality. P. 168.

165. Fine trap, S. W. ¼ of sec. 21, T. 60–6; Pine lake. P. 168.

165A. No. 165 containing fragments of No. 164; same locality. P. 168.

165B. A condition of No. 155 A; same locality. P. 168.

166. Diabasic rock, N. W. ¼ of sec. 28, T. 60–6; Pine lake. P. 168.

167. Diabasic rock, west shore of Pine lake; T. 60–6. P. 168.

168. Very fine diabasic rock, west shore of Pine lake; T. 60–6. P. 168.

169. Very fine diabasic rock, west shore of Pine lake; T. 60–6. P. 168.

170. Micaceous schist, from the syenite; north of Gunflint lake. P. 158.

171. Hornblendic schist, from the syenite; north of Gunflint lake. P. 158.

172. Coarse hornblendic schist, from the syenite; north of Gunflint lake. P. 158.

173. Syenite holding hornblendic schist fragments; north of Gunflint lake. P. 159.

174. Syenitic gneiss, north of Gunflint lake. P. 159.

175. Gabbro, S. W. ¼ of S. E. ¼ sec. 36, T. 65–3; south shore of Mayhew lake. P. 169.

176. Lighter colored gabbro, from end of little point in the S. W. ¼ of S. E. ¼ sec. 36, T. 65–3; Mayhew lake. P. 169.

177. Magnetic iron ore in the gabbro; same locality as No. 176. P. 169.

178. Decayed gabbro; on the line between ranges 2 and 3, just south of Mayhew lake. P. 169.

179. Magnetic iron ore in the gabbro, from the point crossed by the line between secs. 31 and 32, T. 65–2; Iron lake. P. 170.

180. Magnetitic gabbro; same locality as No. 179. P. 170.

181. Fine muscovado-like rock, S. E. ¼ of N. W. ¼ sec. 4, T. 64–2; Portage lake. P. 170.

182. Gabbro, from the little point in the N. W. ¼ of N. E. ¼ of N. W. ¼ sec. 12, T. 64–2; Poplar lake. P. 171.

183. Very fine gabbro, a condition of No. 182; same locality. P. 171.

184. Light gray gabbro with the labradorite collected together in spots; S. E. ¼ of N. E. ¼ sec. 12, T. 64–2; Poplar lake. P. 171.

185. Gabbro, from hill a quarter of a mile north of Meeds' lake, and a little west of the centre of sec. 15, T. 64–2. P. 172.

186. Rough Animike slate, N. W. ¼ of N. E. ¼ sec. 14, T. 64–2; Meeds' lake. P. 172.

187. Gabbro, S. E. ¼ of S. E. ¼ sec. 29, T. 64–2; north shore of Winchell lake. P. 174.

188. Goarse gabbro, from the point crossed by the line between secs. 31 and 32, T. 62–4; south shore of Winchell lake. P. 174.

189. Gabbro, from the bluff in the N. W. ¼ of N. W. ¼ sec. 31, T. 64–2; south shore of Winchell lake. P. 174.

190. Gabbro holding some pinkish feldspar, 20 feet above No. 189. P. 174.

191. Altered gabbro, reddish; ten feet above No. 190. P. 175.

192. Very dark syenite, two feet above No. 191. P. 175.

193. Very dark syenite, two feet above No. 191. P. 175.

194. Fine pinkish-gray syenite, just above No. 193. P. 175.

195. Pinkish-gray syenite, just above No. 194. P. 175.

196. Pinkish-gray syenite, from top of bluff; same locality. P. 175.

197. Showing change from gabbro to syenite; same locality. P. 175.

198. A condition of the gabbro, N. W. ¼ of N. W. ¼ sec. 31, T. 64–2; Winchell lake, north end of portage to Sham lake. P. 175.

199. Altered gabbro, S. W. ¼ of N. W. ¼ sec. 31, T. 64–2; north end of Sham lake, at the portage to Winchell lake. P. 176.

200. Fine red syenite, S. W. ¼ of N. W. ¼ sec. 31, T. 64–2; east side of Sham lake. P. 176.

201. Altered gabbro (?), S. E. ¼ of S. E. ¼ sec. 36, T. 64–3; near the southwest corner of Sham lake. P. 176.

202. Fine red syenite, S. E. ¼ of S. W. ¼ sec. 1, T. 63–3; west side of Lost lake. P. 176.

203. Dark siliceous trap, S. E. ¼ of S. W. ¼ sec. 12, T. 63–3, east side of bay; Brulé lake. P 177.

204. A condition of the gabbro (?) a little south of No. 203. P. 177.

205. Gray feldspar porphyry, from the point in the S. E. ¼ of N. E. ¼ of N. W. ¼ sec. 13, T. 63–3; Brulé lake. P. 177.

206. Dark feldspar porphry; same locality as No. 205. P. 177.

207. Red quartz porphyry; a few yards south of the last. P. 178.

207A. A darker and more siliceous condition of No. 207, near the contact with No. 208; same locality. P. 178.

208. Fine diabase, in contact with No. 207; same locality. P. 178.

209. Diabase-like rock, inclined to be amygdaloidal; small island in the S. E. ¼ of S. E. ¼ sec. 18, T. 63–3; Brulé lake. P. 178.

210. Gabbro, S. W. ¼ of sec. 18, T. 63–3; lake Georgia, a short distance west of the portage from Brulé lake. P. 179.

211. Dark feldspar porphyry; lake Georgia, a short distance west of No. 210. P. 179.

212. Trap; near its contact with the gabbro (No. 213); N. E. ¼ of S. W. ¼ sec. 13, T. 63–4; north side of lake Georgia. P. 179.

212A. Coarser condition of No. 212, farther from the contact. P. 179.

213. Gabbro in contact with trap (No. 212); same locality. P. 179.

214. Fine red syenite, S. W. ¼ of sec. 12, T. 63–4; Surveyor's lake, on the portage going west to Found lake. P. 179.

215. Diabase, S. ½ of sec. 11, T. 63–4; hill on north shore of Found lake. P. 180.

216. Fine red syenite holding pieces of a darker rock; S. ½ of sec. 11, T. 63–4; north shore of Found lake. P. 180.

217. Gabbro, S. W. ¼ of N. E. ¼ sec. 11, T. 63–4; lake Ida Belle. P. 180.

218. Diabase, S. W. ¼ of N. W. ¼ sec. 11, T. 63–4,—just east of the line between secs. 10 and 11; lake Ida Belle. P. 180.

219. Fine diabase from dike in gabbro, little point in the S. E. ¼ of sec. 10, T. 63–4; lake Ida Belle. P. 180.

220. Gabbro cut by the above dike. P. 180.

221. Fine-grained rock resembling "muscovado;" N. W. ¼ of sec. 15, T. 63–4, near the line between secs. 10 and 15; southwest of lake Ida Belle. P. 181.

222. Large crystals of hornblende from vein in gabbro; southwest of lake Ida Belle, near the last locality. P. 181.

223. Gabbro rich in magnetite; southwest of lake Ida Belle, near the last locality. P. 181.

224. Magnetite from the gabbro; N. ½ of sec. 16, T. 63–4, near the line between secs. 9 and 16; southwest of lake Ida Belle. P. 181.

225. Fine red syenite, east side of entrance to the small bay in the N. W. ¼ of N. E. ¼ sec. 10, T. 63–4; lake Ida Belle. P. 181.

226. Diabase from dike in gabbro; same locality as No. 225. P. 181.

227. Gabbro; same locality. P. 181.

228. Fine red syenite underlying the gabbro; north side of small island in the N. E. ¼ of S. E. ¼ sec. 3, T. 63–4; lake Ida Belle. P. 182.

229. Dark rock cut by veins of the following; hill in the E. ½ of sec. 3, T. 63–4; lake Ida Belle. P. 182.

230. Fine red syenite from veins in No. 229; same locality. P. 182.

231. Showing contact of Nos. 229 and 230. P. 182.

232. Fine red syenite from vein in gabbro; S. E. ¼ of sec. 35, T. 64–4, lake Ida Belle; on the portage going north. P. 183.

233. A decayed condition of the gabbro; S. E. ¼ of N. E. ¼ sec. 26, T. 64–4; west shore near the north end of Narrow lake. P. 183.

233½. Muscovado, N. E. ¼ sec. 33, T, 65–4; west shore of Draper lake. P. 184.

234. Fine gray syenite underlying the gabbro; probably in the S. W. ¼ of sec. 29, T. 65–4; on the portage from lake No. 3 to lake No. 4. P. 184.

235. Gabbro overlying No. 234; same locality. P. 184.

236. Muscovado; same locality as No. 234. P. 185.

237. Fine gabbro, probably in S. ½ of sec. 29, T. 65–4; from little island in southern part of lake No. 4. P. 185.

238. Magnetic iron ore from the quartzyte, S. E. ¼ of S. E. ¼ sec. 25, T. 65–5; south shore of Flying Cloud lake, near its eastern end. P. 185.

239. Greenstone; same locality as No. 238. P. 185.

240. Magnetic iron ore from the quartzyte; probably in the S. E. ¼ of S. E. ¼ sec. 26, T. 65–5. P. 186.

241. Greenstone, 12 feet north of No. 240. P. 186.

242. Magnetitic quartzyte, just south of No. 241. P. 186.

243. Magnetitic quartzyte lying on No. 244; probably in the N. W. ¼ of N. E. ¼ sec. 35, T. 65–5. P. 186.

244. Greenstone underlying No. 243; same locality. P. 186.

245. Fine gabbro, from the little point in the N. E. ¼ of N. E. ¼ sec. 14, T. 64–7; Shoo-fly lake. P. 186.

246. Gabbro, west side of the small lake in the S. W. ¼ of sec. 13, T. 64–7. P. 187.

247. Decayed condition of No. 246; west shore, near the south end of the small lake in the S. W. ¼ of sec. 13, T. 64–7. P. 187.

248. Olivinitic iron ore, S. E. ¼ of S. W. ¼ sec. 14, T. 64–7; north side of Fraser lake. P. 187.

249. Coarse hornblende (?) rock; same locality. P. 187.

250. Olivinitic iron ore in No. 249; same locality. P. 187.

251. Magnetitic quartzyte in No. 249; same locality. P. 187.

252. Olivinitic iron ore; same locality. P. 187.

253. Coarse hornblende (?) rock, not as much decayed as No. 249; same locality. P. 187.

254. Muscovado; same locality. P. 187.

255. No. 249 containing considerable magnetite; same locality. P. 187.

256. Same as No. 255 and showing a piece of No. 254; same locality. P. 187.

257. Muscovado from northern foot of the ridge; same locality. P. 188.

258. Magnetitic quartzyte; same locality. P. 188.

259. Magnetitic quartzyte showing banding; same locality. P. 188.

260. Showing contact of the quartzyte and the hornblende rock (No. 249); same locality. P. 188.

261. Fine decayed gabbro, N. W. ¼ of N. E. ¼ sec. 23, T. 64–7; north shore of Fraser lake. P. 188.

262. Olivintic iron ore; same locality. P. 188.

263. Magnetitic quartzyte; same locality. P. 188.

264. Magnetitic quartzyte, showing banding; same locality. P. 188.

265. Band of magnetite from the quartzyte; same locality. P. 188.

266. Muscovado-like rock, from a bed in the quartzyte; same locality. P. 188.

267. Olivinitic iron ore; same locality. P. 189.

268. Large crystals, apparently similar to No. 249, but containing much magnetite; same locality. P. 188.

269. Gabbro, N. E. ¼ of sec. 28, T. 64–7; a quarter of a mile north of Thomas lake. P. 189.

270. Muscovado holding irregular blotches of a light colored feldspar; W. ½ of sec. 27, T. 64–7; north shore of Thomas lake. P. 189.

271. Hornblende (?) rock similar to Nos. 249 and 253, N. E. ¼ of sec. 29, T. 64–7; north shore of Thomas lake. P. 189.

272. Magnetitic quartzyte showing banding on weathered surface; same locality. P. 189.

273. Iron ore, apparently almost pure magnetite; same locality. P. 189.

274. Magnetitic quartzyte; same locality. P. 190.

275. Same as No. 274. P. 190.

276. Pink gabbro holding small quantities of what appears to be a red oxide of iron; east side of the long bay in sec. 15, T. 63–7; lake Alice. P. 191.

277. Gabbro, S. E. ¼ of N. W. ¼ sec. 15, T. 63–7; east shore of lake Alice. P. 191.

278. Green chloritic schist; north of Cady house, Tower. Same as No. 868 (N. H. W.). P. 194.

279. Rough, scarcely banded jasper; 25 feet below the surface; Stone mine, Tower. Same as No. 892 (N. H. W.). P. 194.

280. Red jasper with darker bands of iron ore; Stone mine, Tower. Same as No. 903 (N. H. W.). P. 194.

281. Matrix of conglomerate occurring north of the Cady house, Tower. Same as No. 908 (N. H. W.). P. 194.

282. Breccia, now converted to hematite and a floury white mineral; Breitung mine, Tower. Same as No. 916 (N. H. W.). P. 194.

283. Black or purplish-black clay slate; south shore of Pine island, Vermilion lake; a few feet east of the line between ranges 15 and 16. Same as No. 921 (N. H. W.). P. 194.

284. Sericitic schist, rather siliceous; north shore of Pine island, Vermilion lake; on the line between ranges 15 and 16. P. 192.

285. Sericitic schist; Pine island. P. 192.

286. Green, somewhat sericitic schist; Pine island. P. 192.

287. Green, somewhat graywacke-like rock; Pine island. P. 192.

288. Rough sericitic schist; Pine island. P. 192.

289. Green, somewhat chloritic (?) schist; Pine island. P. 192.

290. Light gray argillaceous slate; Pine island. P. 192.

291. Coarser and rather sericitic condition of No. 290; Pine island. P. 192.

292. Coarser and rather sericitic condition of No. 290; Pine island. P. 192.

293. Coarser and rather sericitic condition of No. 290; Pine island. P. 192.

294. Light gray argillaceous slate; Pine island. P. 192.

295. Gray argillaceous slate; Pine island. P. 192.

296. A more siliceous condition of the slate; Pine island. P. 192.

297. Gray argillaceous slate; Pine island. P. 192.

298. Argillaceous slate showing both the gray and black bands; south shore of Pine island, on the line between ranges 15 and 16. P. 192.

V.

MUSEUM ADDITIONS.

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887-88.

Serial No.	Obtained.		Name.	Number of Specimen.	Locality.	Formation.	Collector and Remarks.
	When.	Whence.					
6191	Jan., 1886......	Geol. Survey......	Gravel, largely limestone........	Indef.	Albert Lea, Minn......	Drillings from the well at Albert Lea	From Mayor A. C. Wedge, 80 feet.
6192	Jan., 1886......	Geol. Survey......	Sand and gravel....................................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 95 feet.
6193	Jan., 1886......	Geol. Survey......	Sand, mainly quartz.............................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 105 feet.
6194	Jan., 1886......	Geol. Survey......	Gravel and sand..................................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 112 feet.
6195	Jan., 1886......	Geol. Survey......	Sand..	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 113 feet.
6196	Jan., 1886......	Geol. Survey......	Sand with magnesian limestone............	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 114 feet.
6197	Jan., 1886......	Geol. Survey......	Magnesian limestone and sand..............	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 115 feet.
6198	Jan., 1886......	Geol. Survey......	Magnesian limestone and sand..............	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 115 feet.
6199	Jan., 1886......	Geol. Survey......	Sand with some limestone....................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 130 feet.
6200	Jan., 1886......	Geol. Survey......	Magnesian limestone......	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 143 feet.
6201	Jan., 1886......	Geol. Survey......	Light-gray shale	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 155 feet.
6202	Jan., 1886......	Geol. Survey......	Light-gray shale..................................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 160 feet.
6203	Jan., 1886......	Geol. Survey......	Battered films of metalic iron...............	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 165 feet.
6204	Jan., 1886......	Geol. Survey......	Gray shale, sandy................................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 172 feet.
6205	Jan., 1886......	Geol. Survey......	Gray shale	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 210 feet.
6206	Jan., 1886......	Geol. Survey......	Gray shale........................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 213 feet.
6207	Jan., 1886......	Geol. Survey......	Calcareous shale.................................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 220 feet.
6208	Jan., 1886......	Geol. Survey......	Compact, light-colored limestone	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 230 feet.
6209	Jan., 1886......	Geol. Survey......	Mainly magnesian limestone................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 234 feet.
6210	Jan., 1886......	Geol. Survey......	Mainly white quartz sand.........	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 236 feet.
6211	Jan., 1886......	Geol. Survey......	Mainly white quartz sand..........	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 237 feet.
6212	Jan., 1886......	Geol. Survey......	Mainly white quartz sand....................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 240 feet.
6213	Jan., 1886......	Geol. Survey......	Buff magnesian limestone..................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 241 feet.
6214	Jan., 1886......	Geol. Survey......	Buff magnesian limestone....................	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 243 feet.
6215	Jan., 1886......	Geol. Survey......	Reddish-buff magnesian limestone.......	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 245 feet.
6216	Jan., 1889......	Geol. Survey......	Reddish-buff magnesian limestone.......	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 250 feet.
6217	Jan., 1886......	Geol. Survey......	Reddish-buff magnesian limestone.......	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 254 feet.
6218	Jan., 1886......	Geol. Survey......	Reddish-buff magnesian limestone......	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 258 feet.
6219	Jan., 1886.....	Geol. Survey......	Reddish-buff magnesian limestone......	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 260 feet.
6220	Jan., 1886......	Geol. Survey......	Reddish-buff magnesian limestone......	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 265 feet.
6221	Jan., 1886......	Geol. Survey......	Reddish-buff magnesian limestone......	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 270 feet.
6222	Jan., 1866......	Geol. Survey......	Light-gray, cryst. magnesian limestone	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 275 feet.
6223	Jan., 1886......	Geol. Survey......	Buff magnesian limestone	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 285 feet.
6224	Jan., 1886......	Geol. Survey......	Light-buff magnesian limestone...........	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 295 feet.
6225	Jan., 1886......	Geol. Survey......	Vesicular, buff magnesian limestone....	Indef.	Albert Lea, Minn......		From Mayor A. C. Wedge, 300 feet.
6226	Oct., 1885......	Geol. Survey	Drillings, mixed, mainly quartzose sand	Indef.	4 ms. S.E. f. New Ulm.	Cret..........	From C. M Phelps.
6227	Feb., 1886......	Presented..........	Fibrous gypsum	2	Camillus, N. Y.........	....	From N. H. Winchell.

6228	Feb., 1886	Presented	Gypsum	1	Camillus, N. Y.		From N. H. Winchell.	
6229	Feb., 1886	Presented	Gypsum	1	Sandusky, Ohio		From N. H. Winchell.	
6230	Feb., 1886	Presented	Gypsum	2	Ottawa Co., Ohio.		From N. H. Winchell.	
6231	Feb., 1886	Presented	Fibrous gypsum	2	Grand Rapids, Mich.		From N. H. Winchell.	
6232	Feb., 1886	Presented	Wollastonite	1	Rock Harbor, I. Royale		From N. H. Winchell.	
6233	Feb., 1886	Presented	Tufa	2	Marcellus Falls, N. Y.		From N. H. Winchell.	
6234	Feb., 1886	Presented	Calcite	7			From N. H. Winchell.	
6235	Feb., 1886	Presented	Chlorastrolites in rock	1	RockHarbor, I. Royale		From N. H. Winchell.	
6236	Feb., 1886	Presented	Niagara limestone	1	Joliet, Ill.		From N. H. Winchell.	
6237	Feb., 1886	Presented	Feldspathic quartzyte	1	Ann Arbor, Mich		From N. H. Winchell.	
6238	Feb., 1886	Presented	Aphanite	1	Ann Arbor, Mich		From N. H. Winchell.	
6239	Feb., 1886	Presented	Gneiss	1	Ann Arbor, Mich		From N. H. Winchell.	
6240	Feb., 1886	Presented	Gneiss	1	Ann Arbor, Mich		From N. H. Winchell.	
6241	Feb., 1886	Presented	Feldspathic quartzyte	1	Ann Arbor, Mich		From N. H. Winchell.	
6242	Feb., 1886	Presented	Mottled marble	1	Ann Arbor, Mich		From N. H. Winchell.	
6243	Feb., 1886	Presented	Buhr stone	1	Ohio		From N. H. Winchell.	
6244	Feb., 1886	Presented	Celestite	Indef	Pt. aux Peaux		From N. H. Winchell.	
6245	Feb., 1886	Presented	Drillings, sand, 20 feet	Indef.	Gibbon, Sibley Co.		From Andrew Erickson.	Under 275 ft. blue clay.
6246	Feb., 1886	Presented	Drillings, remains of wood, fr. No. 6245.	Indef.	Gibbon, Sibley Co.		From Andrew Erickson.	
6247	Feb., 1886	Presented	Drillings, red granite, 30 ft.	Indef.	Gibbon, Sibley Co.		From Andrew Erickson.	
6248	1878.	Geol. Survey.	Catlinite with glacial markings	1	Pipestone Co.	Potsdam	From N. H. Winchell.	
6249	March, 1886	Presented	Silver ore (pulverized)	1	Newburyport, Mass.		From G. R. Lumsden, Orig. No. 1.	
6250	March, 1886	Presented	Quartz crystals	Indef.	N. Stonington, Conn.		From G. R. Lumsden, Orig. No. 2.	
6251	March, 1886	Presented	Sillimanite and zircon w. crys. of monosite	Indef.	Norwich Falls, Conn.		From G. R. Lumsden, Orig. No. 3.	
6252	March, 1886	Presented	Prehnite	1	Hartford, Conn		From G. R. Lumsden, Orig. No. 4.	
6253	March, 1886	Presented	Asbestos	1	New Haven, Conn.		From G. R. Lumsden, Orig. No. 5.	
6254	March, 1886	Presented	Amethyst	1	Nova Scotia		From G. R. Lumsden, Orig. No. 6.	
6255	March, 1886	Presented	Brucite and chondrodite	1	Hoboken, N. J.		From G. R. Lumsden, Orig. No. 7.	
6256	March, 1886	Presented	Magnetic iron ore	1	New Jersey		From G. R. Lumsden, Orig. No. 8.	
6257	March, 1886	Presented	Micaceous iron ore	1	Africa		From G. R. Lumsden, Orig. No. 151.	
6258	March, 1886	Presented	Enstatite	1	Chester Co., Pa.		From G. R. Lumsden, Orig. No. 11.	
6259	March, 1886	Presented	Moss Agate	1	Cupar, Scotland		From G. R. Lumsden, Orig. No. 12.	
6260	March, 1886	Presented	Prismatic talc mica	1	Greiner, Tyrol		From G. R. Lumsden, Orig. No. 18.	
6261	March, 1886	Presented	Iron mica	1	Löwenberg, Ger.		From G. R. Lumsden, Orig. No. 20.	
6262	March, 1886	Presented	Rhomboidal graphite	1	Altstadt, Ger.		From G. R. Lumsden, Orig No. 21.	
6263	March, 1886	Presented	Glassy actinolite	1	Zoeptau, Ger.		From G. R. Lumsden, Orig. No. 25.	
6264	March, 1886	Presented	Quartz crystals	1	New Haven, Conn.		From G. R. Lumsden, Orig. No. 26.	
6265	March, 1886	Presented	Basaltic hornblende	1	Schima, Bohemia		From G. R. Lumsden, Orig. No. 26.	
6266	March, 1886	Presented	Selenite	3	Colorado		From G. R. Lumsden, Orig. No. 27.	
6267	March, 1886	Presented	Paraffin, from coal	1			From G. R. Lumsden, Orig. No. 30.	
6268	March, 1886	Presented	Tremolite	1	Tyrol		From G. R. Lumsden, Orig. No. 29.	
6269	March, 1886	Presented	Augite	7	Schima, Bohemia		From G. R. Lumsden, Orig. No. 31.	
6270	March, 1886	Presented	Schiller spar	1	Volpersdorf		From G. R. Lumsden, Orig. No. 32.	
6271	March, 1886	Presented	Plumbago	1	PrestonConn,		From G. R. Lumsden, Orig. No. 33.	
6272	March, 1886	Presented	Moss Agate	1	Sweet-water Co, Wyo.		From G. R. Lumsden, Orig. No. 34.	
6273	March, 1886	Presented	Prismatic Topaz	Indef.	Schneckenstein, Ger.		From G. R. Lumsden, Orig. No. 35.	
6274	March, 1886	Presented	Agate	1	Texas		From G. R. Lumsden, Orig. No. 36.	
6275	March, 1886	Presented	Zircon	1	Brewig, Norway		From G. R. Lumsden, Orig. No. 37.	

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887-88.—(*Continued.*)

Serial No.	Obtained.		Name.	Number of Specimen	Locality.	Formation.	Collector and Remarks.
	When.	Whence.					
6276	March, 1886	Presented	Garnet sand	Indef	Roxbury, Mass		From G. R. Lumsden, Orig. No. 38.
6277	March, 1886	Presented	Iolite	1	Origarfvi, Finland		From G. R. Lumsden, Orig. No. 39.
6278	March, 1886	Presented	Erlane (Breithauptite)	1	Schwarzenberg, Ger.		From G. R. Lumsden, Orig. No. 41.
6279	March, 1886	Presented	Galena	Indef	Dubuque, Iowa		From G. R. Lumsden, Orig. No. 42.
6280	March, 1886	Presented	Asbestos	1	Toronto, Canada		From G. R. Lumsden, Orig. No. 43.
6281	March, 1886	Presented	Garnets	5	Haddam, Conn		From G. R. Lumsden, Orig. No. 44.
6282	March, 1886	Presented	Green Feldspar	4	Rockport, Mass		From G. R. Lumsden, Orig. No. 50.
6283	March, 1886	Presented	Lead Seleuate	1	Durrenberg, Germ		From G. R. Lumsden, Orig. No. 51.
6284	March, 1886	Presented	Mica	1	New Haven, Conn		From G. R. Lumsden, Orig. No. 52.
6285	March, 1886	Presented	Asbestos	1	Norwalk, Conn		From G. R Lumsden, Orig. No. 53.
6286	March, 1886	Presented	Cyanite	1	Greiner, Tyrol		From G. R. Lumsden, Orig. No. 54.
6287	March, 1886	Presented	Asbestos	1	Vermont		From G. R. Lumsden, Orig. No. 55.
6288	March, 1886	Presented	Sodalite	1	Eifel, Germ		From G. R. Lumsden, Orig. No. 56.
6289	March, 1886	Presented	Hayanite	1	Laacher, Germ		From G. R. Lumsden, Orig. No. 57.
6290	March, 1886	Presented	Epidote	2	Franconia, N. H		From G. R. Lumsden, Orig. No. 59.
6291	March, 1886	Presented	Spodumene	1	Sterling, Mass		From G. R. Lumsden, Orig. No. 60.
6292	March, 1886	Presented	Cobalt	3			From G. R. Lumsden, Orig. No. 62.
6293	March, 1886	Presented	Chiastolite	1	Gefrees, Germ		From G. R. Lumsden, Orig. No. 63.
6294	March, 1886	Presented	Porcelainyte	1	Toeplitz, Germ		From G. R. Lumsden, Orig. No. 65.
6295	March, 1886	Presented	Asbestos	Indef	York Co., Pa		From G. R. Lumsden, Orig. No. 68.
6296	March, 1886	Presented	Tripolyte	1	Bilin, Prussia		From G. R. Lumsden, Orig. No. 69.
6297	March, 1886	Presented	Magnetite	1	Rhode Island		From G. R. Lumsden, Orig. No. 74.
6298	March, 1886	Presented	Graphite	1	Ticonderoga, N. Y		From G. R. Lumsden, Orig. No. 76.
6299	March, 1886	Presented	Stibnite	1	Halbermond		From G. R. Lumsden, Orig. No. 77.
6300	March, 1886	Presented	Onyx	1	Oberstein, Germ		From G. R. Lumsden, Orig. No. 78.
6301	March, 1886	Presented	Chloropal	Indef	Madura, India		From G. R. Lumsden, Orig. No. 79.
6302	March, 1886	Presented	Calamine	1	Wiesloch		From G. R. Lumsden, Orig. No. 80.
6303	March, 1886	Presented	Calamine	1	Raibel, Corinthia		From G. R. Lumsden, Orig. No. 82.
6304	March, 1886	Presented	Black mica schist	1	Ames, N. Y		From G. R. Lumsden, Orig. No. 85.
6305	March, 1886	Presented	Wolframite	1	Zirmwald, Bohemia.		From G. R. Lumsden, Orig. No. 87.
6306	March, 1886	Presented	Covellite	1	Pennsylvania		From G. R. Lumsden, Orig. No. 88.
6307	March, 1886	Presented	Iron pyrites	1	Marienberg, Germ		From G. R. Lumsden, Orig. No. 93.
6308	March, 1886	Presented	Hexahedral iron pyrites	1	Alsan, Germ		From G. R. Lumsden. Orig. No. 94.
6309	March, 1886	Presented	Iron and shale	1	York Common, N. Y.		From G. R. Lumsden, Orig. No. 96.
6310	March, 1886	Presented	Petrified cottonwood	1	Colorado		From G. R. Lumsden, Orig. No. 97.
6311	March, 1886	Presented	Hematite	1	Irgang, Bohemia		From G. R. Lumsden, Orig. No. 99.
6312	March, 1886	Presented	Zircon	Indef	Green River, Henderson Co., N. C		From G. R. Lumsden, Orig. No. 100.

6313	March, 1886	Presented	Ferruginous quartz	1	Schellerhan, Germ		From G. R. Lumsden, Orig. No. 102.
6314	March, 1886	Presented	Tremolite	1			From G. R. Lumsden, Orig. No. 106.
6315	March, 1886	Presented	Pisiform ironstone	Indef.	Schafhausen, Germ		From G. R. Lumsden, Orig. No. 107.
6316	March, 1886	Presented	Magnetite	1	Philipstad, Sweden		From G. R. Lumsden, Orig. No 111.
6317	March, 1886	Presented	Siderite	1	Germany		From G. R. Lumsden, Orig. No. 114.
6318	March, 1886	Presented	Native sulphur	1	Sicily		From G. R. Lumsden, Orig. No. 115.
6319	March, 1886	Presented	Red cobalt ochre	1	Schneeberg, Germ		From G. R. Lumsden, Orig. No. 119.
6320	March, 1886	Presented	Copper nickel	1	Schneeberg, Germ		From G. R. Lumsden, Orig. No. 121.
6321	March, 1886	Presented	Variegated copper	1	Freiberg, Germ		From G. R. Lumsden, Orig. No. 125.
6322	March, 1886	Presented	Copper pyrites	1	Siegen, Germ		From G. R. Lumsden, Orig. No. 126.
6323	March, 1886	Presented	Copper pyrites	1	Alsan, Germ		From G. R. Lumsden, Orig. No. 127.
6324	March, 1886	Presented	Gray copper	1	Thuringia		From G. R. Lumsden, Orig. No. 128.
6325	March, 1886	Presented	Red oxyde of copper	1	Dillenberg, Nassau		From G. R. Lumsden, Orig. No. 131.
6326	March, 1886	Presented	Malachite	1	Dillenberg, Nassau		From G. R. Lumsden, Orig. No. 132.
6327	March, 1886	Presented	Blue copper	1	Rheinbreitenbach		From G. R. Lumsden, Orig. No. 133.
6328	March, 1886	Presented	Iron slag	2	Norwich, Conn		From G. R. Lumsden, Orig. No. 137.
6329	March, 1886	Presented	Hepatic mercurial-ore	1	Iddria, Illyrien		From G. R. Lumsden, Orig. No. 138.
6330	March, 1886	Presented	Argentite	1	Freiberg, Germ		From G. R. Lumsden, Orig. No. 140.
6331	March, 1886	Presented	Williamsite	1	Rock Springs, Ind		From G. R. Lumsden, Orig. No. 142.
6332	March, 1886	Presented	Nagyagite	1	Nagyag, Transsylva'a		From G. R. Lumsden, Orig. No. 143.
6333	March, 1886	Presented	Native platina	Indef.	Tagelsk, Ural		From G. R. Lumsden, Orig. No. 144.
6334	March, 1886	Presented	Silver pyrites	1	Mont. Co., N. Y		From G. R. Lumsden, Orig. No. 145.
6335	March, 1886	Presented	Blue iron earth	Indef.	Ebstorf		From G. R. Lumsden, Orig. No. 152.
6336	March, 1886	Presented	Asbestos	Indef.	Canterbury, N. H		From G. R. Lumsden, Orig. No. 153.
6337	March, 1886	Presented	Beryl	1	Canada		From G. R. Lumsden, Orig. No. 157.
6338	March, 1886	Presented	Mica	1	New Jersey		From G. R. Lumsden, Orig. No. 158.
6339	March, 1886	Presented	Brown chalcedony	1	Madura, India		From G. R. Lumsden, Orig. No. 159.
6340	March, 1886	Presented	Brown coal	1	Bruhl, Germ		From G. R. Lumsden, Orig. No. 160.
6341	March, 1886	Presented	Peat	1	Kloster Laach		From G. R. Lumsden, Orig. No. 162.
6342	March, 1886	Presented	Native boracic acid	Indef.	Vulkano		From G. R. Lumsden, Orig. No. 163.
6343	March, 1886	Presented	Hayesine	Indef.	Iquique, Peru		From G. R. Lumsden, Orig. No. 165.
6344	March, 1886	Presented	Brown coal	1	Frierdorf, Bonn		From G. R. Lumsden, Orig. No. 172.
6345	March, 1886	Presented	Nitratine	Indef.	Chili		From G. R. Lumsden, Orig. No. 176.
6346	March, 1886	Presented	Celestite	Indef.	Dornburg, Jena		From G. R. Lumsden, Orig. No. 179.
6347	March, 1886	Presented	Garnet	1	New Hampshire		From G. R Lumsden, Orig. No. 180.
6348	March, 1886	Presented	Crystals of hematite	1	New York		From G. R. Lumsden, Orig. No. 183.
6349	March, 1886	Presented	Emery	1	Naxos (Grecian Isl.)		From G. R. Lumsden, Orig. No. 186.
6350	March, 1886	Presented	Asbestos	Indef.	Greiner, Tyrol		From G. R. Lumsden, Orig. No. 189.
6351	March, 1886	Presented	Calcite	1	Howe's cave, N. Y		From G. R. Lumsden, Orig. No. 192.
6352	March, 1886	Presented	Native lodestone	1	Mt. Calamite, Elba		From G. R. Lumsden, Orig. No. 195.
6353	March, 1886	Presented	Rutile	5	Freiberg, Germ		From G. R. Lumsden, Orig. No. 195 A.
6354	March, 1886	Presented	Corundum (ruby)	Indef.	Capelan Mts		From G. R. Lumsden, Orig. No. 196.
6355	March, 1886	Presented	Corundum (sapphire)	1	Miark, Germ		From G. R. Lumsden, Orig. No. 197.
6356	March, 1886	Presented	Spinel (blue)	1	Sweden		From G. R. Lumsden, Orig. No. 199.
6357	March, 1886	Presented	Spinel (ruby)	Indef.	Candy, Ceylon Isl		From G. R. Lumsden, Orig. No. 200.
6358	March, 1886	Presented	Tremolite	1	New York		From G. R. Lumsden, Orig. No. 202.
6359	March, 1886	Presented	Beryl	1	Haddam, Conn		From G. R. Lumsden, Orig. No. 204.
6360	March, 1886	Presented	Smoky quartz	1	N. Benton, N. H		From G. R. Lumsden, Orig. No. 208.

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887-88.—(*Continued.*)

Serial No.	Obtained.		Name.	Number of Specimen.	Locality.	Formation.	Collector and Remarks.
	When.	Whence.					
6361	March, 1886	Presented	Tourmaline (red)	1	Moravia		From G. R. Lumsden, Orig. No. 209.
6362	March, 1886	Presented	Smoky quartz	3	St. Gothard		From G. R. Lumsden, Orig. No. 212.
6363	March, 1886	Presented	Amethyst	1	Oberstein		From G. R. Lumsden, Orig. No. 213.
6364	March, 1886	Presented	Cat's-eye	1	Hoff in Bavaria		From G. R. Lumsden, Orig. No. 214.
6365	March, 1886	Presented	Pyrolusite	1	New York		From G. R. Lumsden, Orig. No. 216.
6366	March, 1886	Presented	Carnelian	1	Oberstein		From G. R. Lumsden, Orig No. 219.
6367	March, 1886	Presented	Andalusite	2	Lancaster, N. H		From G. R. Lumsden, Orig. No. 223.
6368	March, 1886	Presented	Jasper (globular)	1	Kandem, Baden		From G. R. Lumsden, Orig. No. 224.
6369	March, 1886	Presented	Muscovite	1	New Haven, Conn		From G. R. Lumsden, Orig. No. 226.
6370	March, 1886	Presented	Bog iron ore	1	Ft. Plain, N. Y		From G. R Lumsden, Orig. No. 228.
6371	March, 1886	Presented	Foliated brown coal	1	Ratt, Germany		From G. R. Lumsden, Orig. No. 229.
6372	March, 1886	Presented	Fire opal	Indef.	Zamapan		From G. R. Lumsden, Orig. No. 231.
6373	March, 1886	Presented	Chrysolite	1	Dreis in d. Eifel		From G. R. Lumsden, Orig. No. 232.
6374	March, 1886	Presented	Serpentine	1	New Haven, Conn		From G. R. Lumsden, Orig. No. 233.
6375	March, 1886	Presented	Diopside	3	Rothenkopf, Tyrol		From G. R. Lumsden, Orig. No. 235.
6376	March, 1886	Presented	Bastite	1	Baste in Hartz		From G. R. Lumsden, Orig. No. 236.
6377	March, 1886	Presented	Andularia feldspar	1	Mt. Stella, St. Goth'd		From G. R. Lumsden, Orig. No. 237.
6378	March, 1886	Presented	Actinolite	1	Connecticut		From G. R. Lumsden, Orig. No. 238.
6379	March, 1886	Presented	Agate with stilbite in cavity	1	Partridge Isl., N. S		From G. R. Lumsden, Orig. No. 240.
6380	March, 1886	Presented	Lazulite	1	Krieglach, Styria		From G. R. Lumsden, Orig. No. 241.
6381	March, 1886	Presented	Turquois	Indef.	Khorassan, Persia		From G. R. Lumsden, Orig. No. 242.
6382	March, 1886	Presented	Fluorite	1	Freiberg, Germany		From G. R. Lumsden, Orig. No. 243.
6383	March, 1886	Presented	Vesuvianite	1	Monzoni, Tyrol		From G. R. Lumsden, Orig No. 246.
6384	March, 1886	Presented	Pyrope	Indef.	Meronitz, Bohemia		From G. R. Lumsden, Orig. No. 249.
6385	March, 1886	Presented	Amber	2	Prussia		From G. R. Lumsden, Orig. No. 254.
6386	March, 1886	Presented	Pyrites and lead	1	Mont. County, N. Y		From G. R. Lumsden, Orig. No. 257.
6387	March, 1886	Presented	Galena	1	Pennsylvania		From G. R. Lumsden, Orig. No. 268.
6388	March, 1886	Presented	Gold bearing quartz	1	Mariposa		From G. R. Lumsden, Orig. No. 269.
6389	March, 1886	Presented	Hornstone	1	Vermont		From G. R. Lumsden, Orig. No. 272.
6390	March, 1886	Presented	Beryl	1	New Haven, Conn		From G. R. Lumsden, Orig. No. 277.
6391	March, 1886	Presented	Limestone crystals	1	Kentucky		From G. R. Lumsden, Orig. No. 279.
6392	March, 1886	Presented	Muscovite	1	Connecticut		From G. R. Lumsden, Orig. No. 281.
6393	March, 1886	Presented	Iron pyrites	1	Pennsylvania		From G. R. Lumsden, Orig. No. 288.
6394	March, 1886	Presented	Galena	1	Rossie, N. Y		From G. R. Lumsden, Orig. No. 295.
6395	March, 1886	Presented	Stilbite	1	Sandy Cove, N. S		From G. R. Lumsden, Orig. No. 297.
6396	March, 1886	Presented	Sand (for making glass)	Indef.	Mystic, Conn		From G. R. Lumsden, Orig. No. 299.
6397	March, 1886	Presented	Asbestos	Indef.	Canada		From G. R. Lumsden, Orig. No. 300.

6398	March, 1886	Presented	Leelite	1	Chester Co, Pa.		From G. R. Lumsden, Orig. No. 301.
6399	March, 1886	Presented	Allanite	1			From G. R. Lumsden, Orig. No. 302.
6400	March, 1886	Presented	Asbestos	1	St. Albans, Canada		From G. R. Lumsden, Orig. No. 304.
6401	March, 1886	Presented	Crystals of beryl	1	New London, N. H.		From G. R. Lumsden, Orig. No. 305.
6402	March, 1886	Presented	Garnet sand	Indef.	Sturbridge, Mass		From G. R. Lumsden, Orig. No. 309.
6403	March, 1886	Presented	Crystal of mica	1	Haddam, Conn		From G. R. Lumsden, Orig. No. 310.
6404	March, 1886	Presented	Porcelain and china (from feldspar)	3	Delaware		From G. R. Lumsden, Orig. No. 311.
6405	March, 1886	Presented	Clay, pebbles and pyrites	Indef.	Lake Michigan		From G. R. Lumsden, Orig. No. 312.
6406	March, 1886	Presented	Kaolin	Indef.	Saxony, Germany		From G. R. Lumsden, Orig. No. 318.
6407	March, 1886	Presented	Moon-stone	Indef.	Haddam, Conn		From G. R. Lumsden, Orig. No. 318.
6408	March, 1886	Presented	Garnets	Indef.	Willimantic, Conn		From G. R. Lumsden, Orig. No. 338.
6409	March, 1886	Presented	Garnets	1	New Haven, Conn		From G. R. Lumsden, Orig. No. 340
6410	March, 1886	Presented	Piece of stalagmite	1	Howe's Cave, N. Y		From G. R. Lumsden, Orig. No. 350.
6411	March, 1886	Presented	Foliated sulphate of lime	1	Connecticut		From G. R. Lumsden, Orig. No. 370.
6412	March, 1886	Presented	Asbestos	1	Norwalk, Conn		From G. R. Lumsden, Orig. No. 380.
6413	March, 1886	Presented	Rose quartz	1	New Britain, Conn		From G. R. Lumsden, Orig. No. 410.
6414	March, 1886	Presented	Chrysoberyl	7	Haddam, Conn		From G. R. Lumsden, Orig. No. 414.
6415	March, 1886	Presented	Feldspar	1	Fort Plain, N. Y		From G. R. Lumsden, Orig. No. 415.
6416	March, 1886	Presented	Volcanic glass	Indef.	Crater of Owhyhee		From G. R. Lumsden, Orig. No. 490.
6417	March, 1886	Presented	Beryl (emerald)	Indef.	East Siberia		From G. R. Lumsden, Orig. No. 500.
6418	March, 1886	Presented	Glassy feldspar	1	Drachenfels, Germ		From G. R. Lumsden, Orig. No. 3.
6419	March, 1886	Presented	Gypsum	2			From G. R. Lumsden, Orig. No. 19.
6420	March, 1886	Presented	Iron pyrites	2			From G. R. Lumsden, Orig. No. 22.
6421	March, 1886	Presented	Chalcopyrite, galena and calcite	3			From G. R. Lumsden, Orig. No. 71.
6422	March, 1886	Presented	Siderite	1			From G. R. Lumsden, Orig. No. 91.
6423	March, 1886	Presented	Wood opal	1			From G. R. Lumsden, Orig. No. 109.
6424	March, 1886	Presented	Malachite (earthy)	Indef.			From G. R. Lumsden, Orig. No. 274.
6225	March, 1886	Presented	Tremolite	1			From G. R. Lumsden, Orig. No. 289.
6226	March, 1886	Presented	Black limestone	1			From G. R. Lumsden, Orig. No. 307.
6427	March, 1886	Presented	Agate (polished)	1			From G. R. Lumsden, Orig. No. 390.
6428	March, 1886	Presented	Beryl	5			From G. R. Lumsden, Orig. No. 460.
6429	March, 1886	Presented	Wood jasper	1			From G. R. Lumsden, Orig. No. 470.
6430	March, 1886	Presented	Petrified wood	1			From G. R. Lumsden.
6431	March, 1886	Presented	Concretions	4	Ill ?		From G. R. Lumsden.
6432	Jan., 1886	Presented	Ostrea bellaplicata	10	Sherman, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6433	Jan., 1886	Presented	Ostrea quadriplicata	10	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6434	Jan., 1886	Presented	Ostrea quadriplicata (or allied species)	5	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6435	Jan., 1886	Presented	Ostrea carinata	5	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6436	Jan., 1886	Presented	Gryphæa pitcheri	20	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6437	Jan., 1886	Presented	Gryphæa pitcheri variety	5	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6438	Jan., 1886	Presented	Gryphæa pitcheri variety	5	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6439	Jan., 1886	Presented	Exogyra ariatenum	15	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6440	Jan., 1886	Presented	Exogyra matheroniana	3	Ft. Worth, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6441	Jan., 1886	Presented	Cordium	1	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6442	Jan., 1886	Presented	Corbula graysonensis	2	Sherman, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6443	Jan., 1886	Presented	Lima wacoensis	1	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6444	Jan., 1886	Presented	Neitha texana	3	Denison, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6445	Jan., 1886	Presented	Terebratula wacoensis	15	Ft. Worth, Texas	Cretaceous	From F. A. Sampson, Sedalia, Mo.

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887–88.—(*Continued.*)

Serial No.	Obtained.		Name.	Number of Specimen.	Locality.	Formation.	Collector and Remarks.
	When.	Whence.					
6446	Jan., 1886	Presented	Serpula communis	4	Denison, Tex	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6447	Jan., 1886	Presented	Serpula communis	1	Denison, Tex	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6448	Jan., 1886	Presented	Holaster elegans	2	Denison, Tex	Cretaceous	From F. A. Sampson, Sedalia, Mo.
6451	Jan., 1886	Presented	Chonophyllum sedaliensis, White	4	Sedalia, Mo		From F. A. Sampson, Sedalia, Mo.
6452	Jan., 1886	Presented	Michelina expansa, White	4	Sedalia, Mo		From F. A. Sampson, Sedalia, Mo.
6453	Jan., 1886	Presented	Michelina placenta, White	2	Sedalia, Mo		From F. A. Sampson, Sedalia, Mo.
6454	Jan., 1886	Presented	Zaphrentis calceola, W & W	10	Sedalia, Mo		From F. A. Sampson, Sedalia, Mo.
6455	Jan., 1886	Presented	Flabellum weilesii, Conr	10	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
6456	Jan., 1886	Presented	Turbinola machurii	2	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
6457	Jan., 1886	Presented	Osteodes	5	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
6458	Jan., 1886	Presented	Cellopora	5	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
6459	Jan., 1886	Presented	Cellopora informata, Lonsd	3	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
8460	Jan., 1886	Presented	Heteropora tortilis	5	Jackson, Miss	Tertiary	From F. A. Sampson, Sedalia, Mo.
6461	March, 1886	Exchange	Diabase	1	Near Leesburg, Va		Smithsonian Inst., Washington, D. C.
6462	March, 1886	Exchange	Diabase	1	Addison, Maine		Smith. Inst., Wash., Orig. No. 37,019.
6463	March, 1886	Exchange	Diabase	1	York, Pa		Smith. Ins., Wash., Orig. No. 37,020
6464	March, 1886	Exchange	Diabase	1	Somerville, Mass		Smith. Inst., Wash., Orig. No. 37,683.
6465	March, 1886	Exchange	Olivine diabase	1	Lewiston, Maine		Smith. Inst., Wash., Orig. No. 37,618.
6466	March, 1886	Exchange	Norite	1	Nahant, Mass		Smith. Inst., Wash., Orig. No. 35,931.
6467	March, 1886	Exchange	Melaphyr	1	Brighton, Mass		Smith. Inst., Wash., Orig. No. 26,552.
6468	March, 1886	Exchange	Melaphyr	1	Brighton, Mass		Smith. Inst., Wash., Orig. No. 35,940.
6469	March, 1886	Exchange	Amphibolite	1	Chester, Mass		Smith. Inst., Wash., Orig. No. 37,655.
6470	March, 1886	Exchange	Hypersthene andesite	1	Mt. Shasta, Calif		Smith. Inst., Wash., Orig. No. 36,978.
6471	March, 1886	Exchange	Hornblende andesite	1	Mt. Shasta, Calif		Smith. Inst., Wash., Orig. No. 36,977.
6472	March, 1886	Exchange	Hornblende andesite	1	Mexico, Mexico		Smith. Inst., Wash., Orig. No. 37,711.
6473	March, 1886	Exchange	Elæolite syenite	1	N'r Deckertown, N.J.		Smith. Inst., Wash., D. C.
6474	March, 1886	Exchange	Elæolite syenite	1	S. Litchfield, Maine		Smith. Inst., Wash., Orig. No. 35,935.
6475	March, 1886	Exchange	Rhyolite	1	Zacatecas, Mexico		Smith. Inst., Wash., Orig. No. 37,994.
6476	March, 1886	Exchange	Rhyolite	1	Zacatecas, Mexico		Smith. Inst., Wash., D. C.
6477	March, 1886	Exchange	Rhyolite tuff	1	Zacatecas, Mexico		Smith. Inst., Wash., Orig. No. 37,737.
6478	March, 1886	Exchange	Rhyolite tuff	1	Douglass Co, Colorado		Smith. Inst., Wash., Orig. No. 36,778.
6479	March, 1886	Exchange	Rhyolite tuff	1	Zacatecas, Mexico		Smith. Inst., Wash., Orig, No. 37,693.
6480	March, 1886	Exchange	Basalt	1	Coast of Ireland		Smith. Inst., Wash., Orig. No. 37,610.
6481	March, 1886	Exchange	Basalt	1	Zacatecas, Mexico		Smith. Inst., Wash., Orig. No. 37,786.
6482	March, 1886	Exchange	Leucite basalt	1	Vesuvius, flow of 1872		Smith. Inst., Wash., Orig. No. 36,144.
6483	March, 1886	Exchange	Obsidian	1	Mono Craters, Calif		Smith. Inst, Wash., Orig. No. 29,631.
6484	March, 1886	Exchange	Satin spar	1	Pueblo, Mexico		Smith. Inst., Wash., Orig. No. 37,815.

6487	April, 1886	Geol. Survey	Cryptozoon Minnesotense, Winch	1	Mankato	Shakopee	N. H. Winchell.
6488	April, 1886	Geol. Survey	St. Lawrence limestone	7	St. Lawrence	St. Law	N. H. Winchell.
6490	Sept., 1885	Geol. Survey	Orthis sandbergi, Winchell	1	Red Wing	St. Croix	N. H. Winchell from 6070.
6491	May, 1886	Geol. Survey	Kaolin	Indef.	Redwood Falls	Archæan	N. H. Winchell (from Col. J. B. Clough).
6492	May, 1886	Geol. Survey	Black loam soil Orig. No. 1	Indef.	Tracy, Minn	Drillings of the Tracy deep well.	N. H. Winchell, No. ft. 1, depth 1
6493	May, 1886	Geol. Survey	Yellowish pebbly clay “ 2	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 19, depth 20
6494	May, 1886	Geol. Survey	Blue till “ 3	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 100, depth 120
6495	May, 1886	Geol. Survey	Fine gravel, nearly black “ 4	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 5, depth 125
6496	May, 1886	Geol. Survey	Fine blue clay “ 5	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 20, depth 145
6497	May, 1886	Geol. Survey	Coarse gravel (similar to No. 4) “ 6	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 20, depth 165
6498	May, 1886	Geol. Survey	Fine blue clay “ 7	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 12, depth 177
6499	May, 1886	Geol. Survey	Fine sandstone, homogeneous “ 8	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 20, depth 197
6500	May, 1886	Geol. Survey	Dark gray shale “ 9	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 213, depth 410
6501	May, 1886	Geol. Survey	Fine light blue or greenish sand “ 10	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 60, depth 470
6502	May, 1886	Geol. Survey	Blue clay “ 11	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 43, depth 513
6503	May, 1886	Geol. Survey	Cretaceous grit “ 12	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 32, depth 545
6504	May, 1886	Geol. Survey	Fine gray sandstone “ 13	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 5, depth 550
6505	May, 1886	Geol. Survey	Blue clay like that of 6502 “ 14	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 30, depth 580
6506	May, 1886	Geol. Survey	Angular, rounded grains of sand “ 15	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 7, depth 587
6507	May, 1886	Geol. Survey	Dark unctuous, fine clay “ 16	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 24, depth 611
6508	May, 1886	Geol. Survey	White, kaolinic clay “ 17	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 8, depth 619
6509	May, 1886	Geol. Survey	White and gray quartz sand “ 18	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 8, depth 627
6510	May, 1886	Geol. Survey	Same, but w some kaolinic m't'r'l “ 19	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 10, depth 637
6511	May, 1886	Geol. Survey	White kaolin, with blue clay “ 20	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 25, depth 662
6512	May, 1886	Geol. Survey	White angular quartz sand “ 21	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 2, depth 664
6513	May, 1886	Geol. Survey	Same as last “ 22	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 2, depth 666
6514	May, 1886	Geol. Survey	Same, but finer “ 23	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 6, depth 672
6515	May, 1886	Geol. Survey	White sand w some kaolinic mt'l “ 24	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 18, depth 690
6516	May, 1886	Geol. Survey	Reddish orthoclastic granite “ 25	Indef.	Tracy, Minn		N. H. Winchell, No. ft. 25, depth 715
6517	May, 1886	Geol. Survey	Drillings from Lakewood Cem't'ry well	Indef.	Minneapolis, Minn	......	N. H. Winchell, at 2118 ft.
6518	May, 1886	Presented	Trochus missouriensis (sw)	1	Kansas City, Mo	Coal meas.	From A. M. Light.
6520	Oct., 1886	A. F. Bechdolt	Fossil leaves	29	Nr source Rosebud riv, Mont	......	On Tongue river slope of the Wolf Mts.
6521	Oct., 1886	A. F. Bechdolt	Quercus Winchellii sp. nov	......	“ “	......	Orig. No. 1, 1a From 6520.
6522	Oct., 1886	A. F. Bechdolt	Hamamelites latifolius sp. nov	......	“ “	......	Orig. No. 2, 3d, 4, 5, 11, 11a. 19, 20, 26. From 6520.
6523	Oct., 1886	A. F. Bechdolt	Cratægus Wyomingiana, Lesq	......	“ “	......	Orig. No. 2a, 2b, 7, 7a, 7b, 7c, 7e, 9, 11b, 14, 15, 18, 19a, 22a, 27, 30, and 31. From 6520.
6524	Oct., 1886	A. F. Bechdolt	Artocarpidium intermedium sp. nov	......	“ “	......	Orig. No. 2c, 8. From 6520.
6525	Oct., 1886	A. F. Bechdolt	Ficus producta sp. nov	......	“ “	......	Orig No. 3, 3a, 3b, 3c, 7d, 11c, 11f, 11g, 13a, 14a, 19b, 21a, 22, 28, 29. From 6520.
6526	Oct., 1886	A. F. Bechdolt	Hamamelites latifolius and seed of [V'b'm.	......	“ “	......	Orig. No. 6, 6a. From 6520.
6527	Oct., 1886	A. F. Bechdolt	Quercus ettinghausii sp. nov	......	“ “	......	Orig. No. 10. From 6520.
6528	Oct., 1886	A. F. Bechdolt	Cornus forshammeri Heer	......	“ “	......	Orig. No. 12, 13. From 6520.
6529	Oct., 1886	A. F. Bechdolt	Ficus dura sp. nov	......	“ “	......	Orig. No. 16, 25. From 6520.
6530	Oct., 1886	A. F. Bechdolt	Diospyros, calix of fruit	......	“ “	......	Orig. No. 17. From 6520.
6531	Oct., 1886	A. F. Bechdolt	Viburnum heerii sp. nov	......	“ “	......	Orig. No. 21. From 6520.
6532	Oct., 1886	A. F. Bechdolt	Cornus? specis undeterminable	......	“ “	......	Orig. No. 23. From 6520.
6533	Oct., 1886	A. F. Bechdolt	Seed of Viburnum	......	“ “	......	Orig. No. 24. From 6520.
6534	Oct., 1886	A. F. Bechdolt	Apeilopsis grandifolia sp. nov	......	“ “	......	Orig. No. 32, 33. From 6520.
6535	Oct., 1886	A. F. Bechdolt	Seed of Viburnum? heerii? sp. nov	......	“ “	......	Orig. No. 34. From 6520.
6537	Sept., 1885	H. B. Griffin	Concretion	1	Long Lake, Hennepin Co	Cret.	Forty feet below surface. Presented.

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887-88.—(*Continued.*)

Serial No.	Obtained.		Name.	Number of Specimen.	Locality.	Formation.	Collector and Remarks.
	When.	Whence.					
6538	Sept., 1887	J. W. Bird	Wood	1	Martin Co., Minn	Drift	From a well 68 feet below surface.
6539	Sept., 1887	Hon. C. B. Little	Muscovite	1	Grafton, N. H		Presented.
6540	Sept., 1887	Rev.G.H. Trabert	Agate conglomerate	1	Duluth, Minn	Drift	Presented. From a boulder.
6541	Sept., 1887	York Iron Co	Charcoal	1	Black River Falls		Presented.
6542	Sept., 1887	Exchange	Nickeliferous jasper	1	Riddle, Dougl's Co., Or		From Wm. Q. Brown.
6543	Sept., 1887	Geol. Survey	Iron and copper	1	Tower, Minn		H. V. Winchell. Lee Mine.
6544	Sept., 1887	Geol. Survey	Hematite in quartz	1	Tower, Minn		H. V. Winchell. Lee Mine.
6545	Sept., 1887	Geol. Survey	Quartz crystals	4	Tower, Minn		H. V. Winchell.
6546	Sept., 1887	Geol. Survey	Hematite	1	Tower, Minn		H. V. Winchell.
6547	Sept., 1887	Geol. Survey	Red jasper conglomerate	1	Shores of Rainy Lake	Drift	H. V. Winchell.
6548	Sept., 1887	Geol. Survey	Coarse hornblende quartz	1	Winibigoshish dam		H. V. Winchell. From a boulder.
6549	Sept., 1887	Geol. Survey	Sand	Indef.	Rainy Lake		H. V. Winchell. Sec. 28, 71, 23.
6550	Sept., 1887	Geol. Survey	Iron from furnace	1	Black River Falls		N. H. Winchell.
6553	Nov., 1887	Geol. Survey	Hinckley sandstone	1	Cattle River quarry	Potsdam	N. H. Winchell.
6555	Jan., 1888	Presented	Coarse syenite	2	Red Wing	Drift	From Dr. G. A. Newman.
6556	Feb., 1888	Presented	Conocephalites hamulus, Hall	2	Winona, Minn	Silurian	From W. A. Finkelnburg.
6557	Feb., 1888	Presented	Platyceras minutissimum (Wal.)	3	Marine Mills, Minn	Silurian	From W. A. Finkelnburg.
6558	Feb., 1888	Presented	Bellerophon antiquatus (Wal.)	2	Osceola, Wis	Silurian	From W. A. Finkelnburg.
6559	Feb., 1888	Presented	Lingulepis pinnaformis, Owen	3	Taylors Falls, Minn	Silurian	From W. A. Finkelnburg. Short valve.
6560	Feb., 1888	Presented	Lingulepis pinnaformis	3	Taylors Falls, Minn	Silurian	From W. A. Finkelnburg. Long valve.
6561	Feb., 1888	Presented	Obolella polita, Hall	4	Dresbach, Minn	Silurian	From W. A. Finkelnburg.
6562	Feb., 1888	Presented	Chariocephalus whitfieldi, Hall	2	Wis. opp. Winona, M.	Silurian	From W. A. Finkelnburg. Glabella.
6563	Feb., 1888	Presented	Dikelocephalus osceola (Hall)	1	Osceola Mills, Wis	Silurian	From W. A. Finkelnburg. Head.
6564	Feb., 1888	Presented	Dikelocephalus osceola	1	Osceola Mills, Wis	Silurian	From W A. Finkelnburg. Pygidium.
6565	Feb., 1888	Presented	Conocephalites minors Shum	3	Minneiska, Minn	Silurian	From W. A. Finkelnburg. Glabella.
6566	Feb., 1888	Presented	Conocephalites, Oweni Hall	4	Marine Mills, Minn	Silurian	From W.A. F'g. Glabella, fixed cheeks.
6567	Feb., 1888	Presented	Illænurus quadratus, Hall	2	Osceola Mills, Wis	Silurian	From W. A. Finkelnburg. Free cheeks.
6568	Feb., 1888	Presented	Illænurus quadratus	3	Osceola Mills, Wis	Silurian	From W. A. Finkelnburg. Glabella.
6569	Feb., 1888	Presented	Illænurus quadratus	2	Osceola Mills, Wis	Silurian	From W. A. Finkelnburg. Pygidium.
6570	Feb., 1888	Presented	Palæomæa minneiskænsis, Wal	3	Minneiska, Minn	Silurian	From W. A. Finkelnburg.
6576	Feb., 1888	Exchange	Felsyte	1	Sec.17, T.33, R.5(E), Mo		From Erasmus Haworth, Orig. No. 316
6577	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 9, [illegible]. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 317
6578	Feb., 1888	Exchange	Quartz-porphory	1	Sec. 16, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 318
6579	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec. 16, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 319
6580	Feb., 1888	Exchange	Granite	1	Sec. 9, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 320
6581	Feb., 1888	Exchange	Quartz-porphyry	1	Missouri		From Erasmus Haworth, Orig. No, 321

6582	Feb., 1888	Exchange	Quartz-ironstone	1	Sec. 9, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 322
6583	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 9, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 323
6584	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 18, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 324
6585	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 9, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 325
6586	Feb., 1888	Exchange	Granite	1	Sec. 11, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 326
6587	Feb., 1888	Exchange	Granite	1	Sec. 9, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 327
6588	Feb., 1888	Exchange	Quartz-orthoclase	1	Sec. 20, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 328
6589	Feb., 1888	Exchange	Porphyry-orthoclase	1	Sec. 29, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 329
6590	Feb., 1888	Exchange	Porphyry-orthoclase	1	Sec. 21, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 330
6591	Feb., 1888	Exchange	Porphyry-orthoclase	1	Sec. 28, T. 33, R. 5, Mo		From Erasmus Haworth, Orig. No. 331
6592	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec. 29, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 322
6593	Feb., 1888	Exchange		1	Sec. 32, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 333
6594	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec. 32, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 334
6595	Feb., 1888	Exchange	Altered dioryte (?)	1	Sec. 32, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 335
6596	Feb., 1888	Exchange	Chert	1	Sec. 32, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 336
6597	Feb., 1888	Exchange		1	Sec. 32, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 337
6598	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 31, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 338
6599	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 31, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 339
6600	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 6, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 340
6601	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec. 6, T. 32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 341
6602	Feb., 1888	Exchange	Diabase	1	Sec. 16, T. 32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 342
6603	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec. 16, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 343
6604	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec. 15, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 314
6605	Feb., 1888	Exchange	Granite	1	Sec. 15, T. 33, R. 5, Mo		From Erasmus Haworth, Orig. No. 345
6606	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 27, T. 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 347
6607	Feb., 1888	Exchange	Diabase	1	Sec. 17, T. 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 348
6608	Feb., 1888	Exchange	Diabase	1	Sec. 17, T. 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 349
6609	Feb., 1888	Exchange		1	Sec. 19, T. 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 350
6610	Feb., 1888	Exchange		1	Sec. 19, T. 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 351
6611	Feb., 1888	Exchange		1	Sec. 5, T. 32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 352
6612	Feb , 1888	Exchange		1	Mo.		From Erasmus Haworth, Orig. No. 353
6613	Feb., 1888	Exchange		1	Mo.		From Erasmus Haworth, Orig. No. 354
6614	Feb., 1888	Exchange		1	Mo.		From Erasmus Haworth, Orig. No. 355
6615	Feb., 1888	Exchange		1	Mo.		From Erasmus Haworth, Orig. No. 356
6616	Feb., 1888	Exchange		1	Mo.		From Erasmus Haworth, Orig. No. 357
6617	Feb., 1888	Exchange	Duplicate samples	14	Mo.		From Erasmus Haworth, Orig. No. .....
6618	Feb., 1888	Exchange	Altered diabase (?)	1	Sec. 4, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 358
6619	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 19, T, 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 360
6620	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 14, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 361
6621	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 18, T, 33, R. 6, Mo.		From Erasmus Haworth, Orig. No. 362
6622	Feb., 1888	Exchange	Granite	1	Sec. 4, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 363
6623	Feb., 1888	Exchange	Granite	1	Sec. 3, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 364
6624	Feb., 1888	Exchange	Diabase	1	Sec. 3, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 365
6625	Feb., 1888	Exchange	Diabase-porphyry	1	Sec. 10, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 366
6626	Feb., 1888	Exchange	Granite	1	Sec. 10, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 367
6627	Feb., 1888	Exchange	Granite	1	Sec. 11, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig No. 368
6628	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 11, T, 33, R. 5. Mo.		From Erasmus Haworth, Orig. No. 369
6629	Feb., 1888	Exchange	Diabase	1	Sec. 14, T, 33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 370

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887-88.—(*Continued.*)

Serial No.	Obtained.		Name.	Number of Specimens.	Locality.	Formation.	Collector and Remarks.
	When.	Whence.					
6630	Feb., 1888	Exchange	Granite	1	Sec.14, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 371
6631	Feb., 1888	Exchange	Quartz-porphyry	1	Sec.14, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 372
6632	Feb., 1888	Exchange	Decomposed conglomerate	1	Sec.13, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 373
6633	Feb., 1888	Exchange	Quartz-porphyry	1	Sec.13, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 374
6634	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.13, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 375
6635	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.24, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 376
6636	Feb., 1888	Exchange	Diabase	1	Sec.25, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 377
6637	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.25, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 378
6638	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.26, T.33, R. 5, Mo.		From Erasmus Haworth, Orig. No. 379
6639	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.35, T.33, R. 5, Mo.		From Errsmus Haworth, Orig. No. 380
6640	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec. 3, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 381
6641	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 3, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 382
6642	Feb., 1888	Exchange	Quartz-orthoclase-porphyry	1	Sec.10, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 383
6643	Feb., 1888	Exchange		1	Sec.16, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 384
6644	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.21, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 385
6645	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.21, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 386
6646	Feb., 1888	Exchange	Plagioclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 387
6647	Feb., 1888	Exchange	Altered diabase	1	Mo.		From Erasmus Haworth, Orig. No. 388
6648	Feb., 1888	Exchange	Plagioclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 389
6649	Feb., 1888	Exchange	Plagioclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 390
6650	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.17, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 391
6651	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.20, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 392
6652	Feb., 1888	Exchange	Marble	1	Sec.18, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 393
6653	Feb., 1888	Exchange	Limestone	1	Sec.19, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 394
6654	Feb., 1888	Exchange	Quartzyte	1	Sec.19, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 395
6655	Feb., 1888	Exchange	Quartz-porphyry	1	Sec. 7, T.32, R. 5, Mo.		From Erasmus Haworth. Orig. No. 396
6656	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec. 7, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 397
6657	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec. 8, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 398
6658	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.30, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 399
6659	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec.30, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 400
6660	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.19, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 401
6661	Feb., 1888	Exchange	Orthoclase-porphyry	1	Sec.15, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 402
6662	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.14, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 403
6663	Feb., 1888	Exchange	Plagioclase-porphyry	1	Sec.23, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 404
6664	Feb., 1888	Exchange	Altered diabase	1	Sec.23, T.32, R. 5, Mo.		From Erasmus Haworth, Orig. No. 405
6665	Feb., 1888	Exchange	Plagioclase-porphyry	1	Mo.		From Erasmus Haworth, Orig. No. 406

6666	Feb., 1888.....	Exchange..........	Plagioclase-porphyry..........	1	Mo.	....	From Erasmus Haworth, Orig. No. 407
6667	Feb., 1888.....	Exchange..........	Epidote-porphyry..........	1	Mo.	....	From Erasmus Haworth, Orig. No. 408
6668	Feb., 1888.....	Exchange..........	Quartz-orthoclase-porphyry..........	1	Mo.	....	From Erasmus Haworth, Orig. No. 409
6669	Feb., 1888.....	Exchange..........	Quartz-orthoclase-porphyry..........	1	Mo.	....	From Erasmus Haworth, Orig. No. 410
6670	Feb., 1888.....	Exchange..........	Diabase..........	1	Mo.	....	From Erasmus Haworth, Orig. No. 411
6671	Feb., 1888.....	Exchange..........	Orthoclase-porphyry..........	1	Mo.	....	From Erasmus Haworth, Orig. No. 412
6672	Feb., 1888.....	Exchange..........	Orthoclase-porphyry..........	1	Mo.	....	From Erasmus Haworth, Orig. No. 413
6673	Feb., 1888.....	Exchange..........	Diabase..........	1	Mo.	....	From Erasmus Haworth, Orig. No. 414
6674	Feb., 1888.....	Exchange..........	Diabase..........	1	Mo.	....	From Erasmus Haworth, Orig. No. 415
6675	Feb., 1888.....	Exchange..........	Diabase..........	1	Mo.	....	From Erasmus Haworth, Orig. No. 416
6676	Feb., 1888.....	Exchange..........	Rewdanskite (?)..........	1	Riddles, Oregon..........	....	From W. Q. Brown.
6677	Feb., 1888.....	Exchange..........	Garnierite and serpentine..........	1	Riddles, Oregon..........	....	From W. Q. Brown.
6678	Feb., 1888.....	Exchange..........	Chrysoprase..........	1	Riddles, Oregon..........	....	From W. Q. Brown.
6679	Feb , 1888.....	Exchange..........	Garnierite (soft)..........	1	Riddles, Oregon..........	....	From W. Q. Brown.
6680	Feb., 1888.....	Exchange..........	Garnierite and chromic iron..........	1	Riddles, Oregon..........	....	From W. Q. Brown.
6681	Feb., 1888.....	Presented..........	Copper ore..........	1	Globe City, Arizona..	....	From J. L. Vivian.
6682	Feb., 1888.....	Presented..........	....	1	....	....	....
6683	April, 1888....	Presented..........	Geyserite..........	Indef.	Lindsborg, Kans..........	....	From J. H. Udden.
6684	April, 1888....	Exchange..........	Pentamerus oblongus, Saw..........	2	Springfield, Ohio..........	Niagara.....	From W. S. Hoskinson.
6685	April, 1888....	Exchange..........	Zaphrentis..........	2	Delaware Co., Ohio...	Dev. Corn...	From W. S. Hoskinson.
6686	April, 1888....	Exchange..........	Zaphrentis..........	2	Delaware Co., Ohio...	Dev. Corn..	From W. S. Hoskinson.
6687	April, 1888....	Exchange..........	Orthocerata..........	2	New Carlisle, Ohio....	Clinton......	From W. S. Hoskinson.
6688	April, 1888....	Exchange..........	Orthocerata..........	1	New Carlisle, Ohio....	Clinton......	From W. S. Hoskinson.
6689	April, 1888....	Exchange..........	Orthocerata..........	1	Miamisburg, Ohio.....	U.H'dn riv	From W. S. Hoskinson.
6690	April, 1888....	Exchange..........	Cyathophylloid..........	3	Springfield, Ohio......	Niagara.....	From W. S. Hoskinson.
6691	April, 1888....	Exchange..........	Cyathophylloid..........	4	New Carlisle, Ohio...	Clinton......	From W. S. Hoskinson.
6692	April, 1888....	Exchange..........	Strophodonta-hemispherica..........	1	Delaware Co., Ohio...	Dev. Corn..	From W. S. Hoskinson.
6693	April, 1888....	Exchange.........	Strophomena-rhomboidalis..........	2	Waldron, Ind..........	Niagara.....	From W. S. Hoskinson.
6694	April, 1888....	Exchange..........	Strophomena-rhomboidalis..........	2	New Carlisle, Ohio...	Clinton......	From W. S. Hoskinson.
6695	April, 1888....	Exchange..........	Illænus daytonensis..........	4	New Carlisle, Ohio...	Clinton......	From W. S. Hoskinson.
6696	April, 1888....	Exchange..........	Streptelamina..........	4	Miamisburg, Ohio.....	L. Sil........	From W. S Hoskinson.
6697	April, 1888....	Exchange..........	Favosites..........	2	Delaware Co., Ohio...	Dev. Corn.	From W. S. Hoskinson.
6698	April, 1888....	Exchange..........	Favistella..........	2	New Carlisle, Ohio...	Clinton	From W. S.Hoskinson.
6699	April, 1888....	Exchange..........	....	2	....	Dev. Corn..	From W. S. Hoskinson.
6700	April, 1888....	Exchange..........	....	1	Miamisburg, Ohio.....	Cincin	From W. S. Hoskinson.
6701	April, 1888....	Exchange..........	Lithostration..........	1	Springfield, Ohio.......	Niagara.....	From W. S. Hoskinson.
6702	April, 1888....	Exchange..........	Eucalyptocrinus crassus..........	3	Springfield, Ohio......	Niagara.....	From W. S. Hoskikson.
6703	April, 1888....	Exchange..........	Eucalyptocrinus crassus..........	2	Waldron, Ind..........	....	From W. S Hoskinson.
6704	April, 1888....	Exchange..........	Eucalyptocrinus (roots)..........	2	Waldron, Ind..........	....	From W. S. Hoskinson.
6705	April, 1888....	Exchange..........	Crinoid stems..........	8	New Carlisle, Ohio...	Clinton......	From W. S. Hoskinson.
6706	April, 1888....	Exchange..........	Crinoid..........	1	Springfield, Ohio......	Niagara.....	From W. S. Hoskinson.
6707	April, 1888....	Exchange..........	Monticulipora dalii..........	2	Miamisburg, Ohio.....	....	From W. S. Hoskinson.
6708	April, 1888....	Exchange..........	Calymene niagarensis..........	1	Springfield, Ohio......	....	From W. S. Hoskinson.
6709	April, 1888....	Exchange..........	Calymene senaria..........	1	Oxford, Ohio..........	U. Hud. riv	From W. S. Hoskinson.
6710	April, 1888....	Exchange..........	Lichas brevipes..........	1	New Carlisle, Ohio...	Clinton......	From W. S. Hoskinson.
6711	April, 1888....	Exchange..........	Spirifera mucronata..........	1	Miamisburg, Ohio.....	....	From W. S. Hoskinson.
6712	April, 1888....	Exchange..........	Atrypa reticularis..........	4	Delaware Co., Ohio...	Dev. Corn..	From W. S. Hoskinson.
6713	April, 1888....	Exchange..........	Platystoma niagarense..........	2	New Carlisle, Ohio...	Clinton	From W. S. Hoskinson.

SPECIMENS REGISTERED IN THE GENERAL MUSEUM IN 1887-88.—(*Concluded.*)

Serial No.	Obtained.		Name.	Number of Specimens.	Locality.	Formation.	Collector and Remarks.
	When.	Whence.					
6714	April, 1888	Exchange	Platystoma niagarense	6	Waldron, Ind		From W. S. Hoskinson
6715	April, 1888	Exchange	Eichwaldia reticulata	2	Waldron, Ind	Niagara	From W. S. Hoskinson.
6716	April, 1888	Exchange	Zygospira modesta	3	Miamisburg, O		From W. S. Hoskinson.
6717	April, 1888	Exchange	Leptæna sericea	3	Miamisburg, O	Up. Hud. R	From W. S. Hoskinson.
6718	April, 1888	Exchange	Protarea vetusta, Hall	2	Miamisburg, O		From W. S. Hoskinson.
6719	April, 1888	Exchange	Murchisonia bellicincta	2	Miamisburg, O		From W. S. Hoskinson.
6720	April, 1888	Exchange	Cyclonema bilix	1	Miamisburg, O		From W. S. Hoskinson.
6721	April, 1888	Exchange	Pleurotomaria tropidophora	2	Miamisburg, O		From W. S. Hoskinson.
6722	April, 1888	Exchange	Orthis sinuata	2	Miamisburg, O	Up. Hud. R	From W. S. Hoskinson.
6723	April, 1888	Exchange	Orthis subquadrata	9	Miamisburg, O		From W. S. Hoskinson.
6724	April, 1888	Exchange	Orthis acutilirata	4	Miamisburg, O		From W. S. Hoskinson.
6725	April, 1888	Exchange	Orthis lynx	5	Miamisburg, O		From W. S. Hoskinson.
6726	April, 1888	Exchange	Orthis faustra	1	New Carlisle, O	Clinton	From W. S. Hoskinson.
6727	April, 1888	Exchange	Streptorhynchus sulcatus	1	Miamisburg, O	Up. Hud. R	From W. S. Hoskinson.
6728	April, 1888	Exchange	Streptorhynchus planumbonus	3	Miamisburg, O		From W. S. Hoskinson.
6729	April, 1888	Exchange	Streptorhynchus nutans	3	Miamisburg, O		From W. S. Hoskinson.
6730	April, 1888	Exchange	Strophomena alternata	2	Miamisburg, O		From W. S. Hoskinson.
6731	May, 1888	Presented	Pseudomorph of magnetite and pyrite after garnet	1	Negaunee, Mich		From N. H. Winchell.
6732	May, 1888	Presented	Rock 60 feet from surface	4	Little Falls, Minn		From N. H. Winchell, at L. F's Brew'y.
6733	May, 1888	Presented	Pyrite from blue till	1	Minnesota	Drift	From N. H. Winchell.
6734	May, 1888	Presented	Pseudomorph hematite	1	Marquette i. r., Mich.		From N. H. Winchell.
6735	May, 1888	Exchange	Tin ore	1	Pennington Co., Dak.		From Sam. Scott, Morgan's Tin Mine.
6736	May, 1888	Exchange	Greisen rock	1	Pennington Co., Dak.		From Sam. Scott, Everly Tin Mine.
6737	May, 1888	Exchange	Spodumene	1	Pennington Co., Dak.		From Sam. Scott, Etta Tin Mine.
6738	May, 1888	Exchange	Rose quartz	1	Pennington Co., Dak.		From Sam. Scott, Red Rose Mine.
6739	May, 1888	Exchange	Albite	1	Pennington Co., Dak.		From Sam. Scott, Etta Tin Mine.
6740	May, 1888	Presented	Albite	2	Amelia Co., Va		G. L. English & Co., Amelia C't House.
6741	May, 1888	Presented	Lingula acuminata	1	New York	Medina Sand.	From Rev. H. Herzer.
6770	Aug., 1888	Presented	Piece of cedar wood	1	Near Camden, Minn.	Drift	From Cyrus R. Stone.
6824	Oct., 1888	Presented	Minerals from Mt Vesuvius	12	Italy		From Mrs. M. J. Wilkin.
6825	Oct., 1888	Presented	Incrustation on gneiss	1	Near Swarthm're col, Pa.		From Miss M. L. Sanford.
6826	Oct., 1888	Presented	Meerschaum	1	Norway		Prof. J. Breda (From the edge of a glacier below Sulitind, Norway.)
6527	Oct., 1888	Presented	Lignite	1	St. Paul, Minn	Drift	Prof. N. H. Winchell.

VI.

APPENDIX.—LIST OF RECENT GEOLOGICAL PUBLICATIONS RELATING TO THE CRYSTALLINE ROCKS.

VI.

LIST OF AMERICAN PUBLICATIONS BETWEEN 1872 AND 1889 THAT HAVE SOME RELATION TO THE CRYSTALLINE ROCKS OF THE NORTHWEST.

This list of publications, while embracing most of those issued since 1872 bearing on the crystalline rocks of Minnesota, or of the Northwest, is not presumed to be complete, and it is desired that geologists who discover omissions will communicate with the writer in order that, in a future report, such additions may be made as will make the list perfect.

The list of papers and other publications prepared by Whitney & Wadsworth and published in the *Bulletin of the Museum of Comparative Zoology*, Cambridge (Geol. Series, Vol. I.), carried the record up to 1880. By the aid of that, and with the assistance of Mr. Geo. H. Barton, of the Institute of Technology, Boston, who examined some serial publications that could not be consulted at Minneapolis, the catalogue may be considered to embrace most of the publications of American geologists on the crystalline rocks of the central and eastern portions of the United States and of Canada, between 1872 and 1889. There are, however, some important serials that have not been consulted.

1873.

BELL, ROBT.

Report on the country between lake Superior and lake Winnipeg. Geol. Sur. of Can., Report of Progress. Montreal, 1872-73, pp. 87-111.

BROOKS, T. B.

Geological Survey of Michigan, with maps, 1869-73, i.; Part I., Iron-bearing Rocks, 319 pp.; Part II., Copper-bearing Rocks, R. Pumpelly and A. R. Marvine, 143 pp.; Part III., Palæozoic Rocks, Charles Rominger, 105 pp.; ii., 298 pp., contains papers by Messrs. Brooks, Julien, Wright, Jenney, and Tuttle.

DANA, J. D.

On the Quartzite, Limestone, and Associated Rocks of the vicinity of Great Barrington, Mass., Am. J. Sci., 3d Series, Vol. 5, pp. 47-53, 87-91; Vol. 6, pp. 257-278.

FOSTER, J. W.

Ancient Mining by the Mound-builders in the "Prehistoric Races of the United States." Chicago, 1873, pp. 361–374.

HITCHCOCK, C. H.

Classification of the Rocks of New Hampshire. Proc. Boston Soc. Nat. Hist., Vol. 15, pp. 304–307.

HUNT, T. STERRY.

The Geology of the North Shore of Lake Superior. (Supplementary Note.) Trans. Am. Inst. Min. Eng., 1873, ii., 58, 59.

IRVING, ROLAND D.

On some points in the Geology of Northern Wisconsin. Trans. Wisc. Acad. Sci., 1873–74, ii., 107–119.

MARVINE, A. R.

Geology of Michigan. Part II., 1873.

NICHOLSON, H. ALLEYNE.

On the Geology of the Thunder bay and Shabendowan Mining Districts on the North Shore of lake Superior. Quart. Jour. Geol. Soc., 1873, xxix., 17–24.

PUMPELLY, RAPHAEL.

The Paragenesis and Derivation of Copper and its Associates on lake Superior. Am. Jour. Sci., 1872 (3), iii., 188–198, 243–258, 347–353; Leonhard's Jahrbuch, 1872, pp. 538–540; Geol. of Michigan, Part II., 1873.

SELWYN, ALFRED R. C.

Notes of a Geological Reconnoissance from lake Superior to Fort Garry. Geol. Surv. of Canada, Report of Progress. Montreal, 1872–73, pp. 8–18.

WHITTLESEY, CHARLES.

On the cause of the Transient Fluctuations of Level in lake Superior. Proc. Am. Assoc. Adv. Sci., 1873, xxii., Part II., 42–46.

WINCHELL, ALEXANDER.

The Diagonal System in the Physical Features of Michigan. Am. Jour. Sci., 1873 (3), vi., 36–40.

WINCHELL, N. H.

Geological and Natural History Survey of Minnesota. First annual report, 113 pp.

WING, A. T.

Concerning the Spontaneous Movements and Fractures of Rock, at Quarry of W. N. Flynt, Monson, Mass. Proc. Bost. Soc. Nat. Hist., Vol. 16, pp. 41–42.

1874.

ALLEN, J. A.

Metamorphism Produced by the Burning of Lignite Beds in Dakota and Montana Territories. Proc. Boston Soc. Nat. Hist., Vol. 16, pp. 246–262.

BROWN, A. J.

The Formation of Fissures and the Origin of Their Mineral Contents. Trans. Am. Inst. Min. Eng., 1874, ii., 215–219.

DANA, JAMES D.

Manual of Geology, New York, 1st ed., 1862, 800 pp.; 2d ed., 1874, 828 pp.; 3d ed., 1880, 911 pp.

DOUGLAS, JAMES.

The Native Copper Mines of lake Superior. Quart. Jour. Sci., 1874, xi., 162–180; Canadian Nat. and Geol., 1874 (2), vii., 318–336.

IRVING, ROLAND D.

On the Age of the Copper-bearing Rocks of lake Superior; and on the Westward Continuation of the lake Superior Synclinal. Am. Jour. Sci., 1874 (3), viii., 46–56.

LE CONTE, J. L.

On Coracite, a new ore of Uranium. Am. Jour. Sci., 1874 (2), iii., 173–175.

M'KELLAR, PETER.

Mining on the North Shore of lake Superior. Toronto, 1874, 26 pp.

NEWBERRY, J. S.

The Iron Resources of the United States. International Review, 1874, ii., 754–780.

NICHOLSON, H. ALLEYNE.

On the Mining District on the North Shore of lake Superior. Trans. of North of England Inst. of Min. and Mech. Eng. Newcastle-on-Tyne, 1874–75, xxiv., 237–249, with maps.

WHITTLESEY, CHARLES.

Sudden Fluctuations of Level in Quiet Waters. Records of Observations. Proc. Am. Assoc. Adv. Sci., 1874, xxiii., 139–143.

1875.

AKERMANN, H. W.

Die Kupferführenden Schichten am lake Superior. Sitzungs-Berichte der naturwissenschaftlichen Gesellschaft Isis in Dresden, 1875, pp. 101–105.

BELL, ROBERT.

The Mineral Region of lake Superior. Canadian Nat. and Geol., 1875 (2), vii., 49–51.

BLAKE, WILLIAM P.

The Mass Copper of lake Superior Mines, and the Method of Mining it. Trans. Am. Inst. Mining Engineers, 1875, iv., 110–112.

CHAPMAN, E. J.

An Outline of the Geology of Ontario, based on a Subdivision of the Province into Six Natural Districts. Canadian Jour., 1875 (2), 580–588.

CHESTER, ALBERT H.

On the Percentage of Iron in Certain Ores. Trans. Am. Inst. Min. Eng., 1875, iv., 219.

DODGE, W. W.

Notes on the Geology of Eastern Massachusetts. Proc. Boston Soc. Nat. Hist., Vol. 17, pp. 388–419.

HUNT, T. STERRY.

The Decayed Gneiss of the Hoosac Mountains. Ibid., Vol. 18, pp. 106–108.

The Development of our Mineral Resources. Harper's Magazine, 1875, li., 82–94.

PUMPELLY, RAPHAEL.

On Pseudomorphs of Chlorite after Garnet at Spurr Mountain Iron Mine. Am. Jour. Sci., 1875 (3), x., 17–21.

SAUVAGE, E.

Notice sur les Minerais de Fer du lac Supérieur. Annales des Mines, 1875 (7), viii., 1–35.

WHITTLESEY, CHARLES.

Physical Geology of lake Superior. Proc. Am. Assoc. Adv. Sci., 1875, xxiv., 60–72.

WINCHELL, N. H.

The Geology of the Minnesota Valley. Second Report on the Geol. and Nat. Hist. Surv. of Minnesota, pp. 127–212.

1876.

BELL, ROBERT.

Report on an Exploration in 1875, between James bay and lakes Superior and Huron. Geol. Surv. of Canada, Report of Progress, 1875–76, pp. 294–342.

BRADLEY, FRANK H.

On a Geological Chart of the United States East of the Rocky Mountains and of Canada. Am. Jour. Sci., 1876 (3), xii., 286–291.

BROOKS, T. B.

On the Youngest Huronian Rocks, South of lake Superior, and the Age of the Copper-bearing Series. Am. Jour. Sci., 1876 (3), xi., 206–211.

Classified List of Rocks observed in the Huronian Series, south of lake Superior, etc. Am. Jour. Sci., 1876 (3), xii., 194–204.

BOUVÉ, T. T.

On the Origin of Porphyry. Proc. Boston Soc. Nat. Hist., Vol. 18, pp 217–220.

CHAPMAN, E. J.

On the Leading Geological Areas of Canada. Canadian Jour., 1876 (2), xv., 92–122.

CREDNER, HERMANN.

Elemente der Geologie. 1st ed., 1872; 2nd ed., 1872; 3rd ed., 1876; 699 pp., 4th ed., 1880.

EGGLESTON, THOMAS.

Boracic Acid in lake Superior Iron Ores. Trans. Am. Inst. Min. Eng., 1876, v., 131, 132.

GEINITZ, H. B.

Alexander Winchell: über geologische Verhältnisse in Michigan. Leonhard's Jahrbuch, 1876, pp. 438–440.

HOUGHTON, JACOB, Jr.

The Ancient Copper Miners of lake Superior. Iron, 1876 (N. S.), viii., 168, 169, 199; Swineford's Copper, Iron, and other Material Interests of lake Superior. Marquette, 1876, pp. 78–89.

HUNT, T. STERRY.

On the History of the Crystalline Stratified Rocks. A. A. A. S. Vol. 25, pp. 205–208.

HYATT, ALPHEUS.

Remarks upon above paper, and upon the Geology of Marblehead Neck. Proc. Bost. Soc. Nat. Hist., pp. 220–224.

McCRACKEN, S. B.

The State of Michigan, embracing Sketches of its History, Position, Resources, and Industries. Lansing, 1876, pp. 48–69.

ROMINGER, CHARLES.

Observations on the Ontonagon Silver Mining Districts and Slate Quarries of Huron bay. Geol. Surv. of Michigan, 1876, iii., 153–166.

SWEET, E. T.

Notes on the Geology of Northern Wisconsin. Trans. Wisc. Acad., 1875–76, iii., 40–55.

SWINEFORD, A. P.

History and Review of the Copper, Iron, Silver, Slate, and other Material Interests of the South Shore of lake Superior. Marquette, Mich., 1876.

WHITTLESEY, CHARLES.

On the Origin of Mineral Veins. Proc. Am. Assoc. Adv. Sci., 1876, xxv., 213–216.

1877.

BELL, ROBERT.

Report on Geological Researches North of lake Huron and East of lake Superior. Geol. Surv. of Canada, Report of Progress, 1876–77, pp. 193–220.

COURTES, W. M.

The North Shore of lake Superior as a Mineral-bearing District. Trans. Am. Inst. Min. Eng., 1877, v., 473–487.

EGGLESTON, THOMAS.

Copper Mining on lake Superior. Trans. Am. Inst. Min. Eng., 1877, vi., 275–312.

The Conglomerates of lake Superior, and the Methods of Dressing Copper. Trans. Am. Inst. Min. Eng., 1877, v., 606–611.

IRVING, ROLAND D.

Note on the Age of Crystalline Rocks of Wisconsin. Am. Jour. Sci., 1877 (3), xiii., 307–309.

ROLKER, CHARLES M.

The Allouez Mine and Ore Dressing, as practiced in the lake Superior Copper District. Trans. Am. Inst. Min. Eng., 1877, v., 584–606.

STRENG and KLOOS.

Ueber die Krystallinischen Gesteine von Minnesota in Nord-Amerika. Neues Jahrbuch für Mineralogie, Geologie und Palæontologie, 1877, 31–56, 113–138 and 225–242. (Translation in the eleventh annual report of the Geological Survey of Minnesota.)

WADSWORTH, M. E.

Notes on the Mineralogy and Petrography of Boston and Vicinity. (Containing Bibliography of Subject.) Proc. Boston Soc. Nat. Hist., Vol. 19, pp. 217–37.

On the Granite of North Jay, Me. Ibid., pp. 237–38.

1878.

CHAMBERLIN, T. C.

Geology of Wisconsin, 1873–77, ii., 768 pp., with maps. Reports by Messrs. I. A. Lapham, O. W. Wight, T. C. Chamberlin, R. D. Irving, C. E. Wright and Moses Strong.

CLAYPOLE, E. W.

On the Pre-Glacial Geography of the Region of the Great Lakes. Canadian Nat. and Geol., 1878 (2), viii., 187–206.

DANA, JAMES D.

Manual of Mineralogy and Lithology. New York, 1878, 474 pp.

HUNT, T. STERRY.

Chemical and Geological Essays. Boston, 1874, 489 pp.; Revised Edition, Salem, 1878.

Azoic Rocks, Part I., 1878. Second Geol. Surv. of Penn., E, 253 pp.

On the Geology of the Eözoic Rocks of North America. (Abstract.) Proc. Boston Soc. Nat. History, Vol. 19, pp. 275–79.

LE CONTE, JOSEPH.

Elements of Geology; a text-book for colleges and for the general reader. New York, D. Appleton & Co., 588 pp., 8vo.

LAFLAMME, L'ABBÉ J. C.

Note sur le Contact des Formations Paleozoiques et Archéennes de la Province de Quebec. Trans. Roy. Soc. Canada, Vol. IV., Sec. IV., pp. 43–47.

MACFARLANE, JAMES.

Geologist's Traveling Hand-book, New York, 1878, 261 pp.

PUMPELLY, RAPHAEL.

Metasomatic Development of the Copper-bearing Rocks of lake Superior Proc. Am. Acad., 1878, xiii., 253–309.

SELWYN, ALFRED R. C.

The Stratigraphy of the Quebec Group and the Older Crystalline Rocks of Canada. Geol. Surv. of Canada, Report of Progress, 1877–78, A. 15 pp. Reprinted in the Canadian Nat. and Geol., 1879 (2), ix., 17–32.

SPENCER, J. W.

Lake Superior.—On the Nipigon or Copper-bearing Rocks of lake Superior, with Notes on Copper Mining in that Region. Canadian Nat. and Geol., 1878 (2), viii., 55–81.

WADSWORTH, M. E.

Notes on the Petrography of Quincy and Rockport. Proc. Bost. Soc. Nat. Hist., xix., pp. 309–16.

WRIGHT, CHARLES E.

First Annual Report of the Commissioner of Mineral Statistics of the State of Michigan for 1877–78. Marquette, 1879, 229 pp.

WINCHELL, N H.

Notes on the Line of the Northern Pacific Railroad, and in Morrison County, Minn. Sixth Report Geol. and Nat. Hist. Surv. Minn., pp. 45–53.

1879.

BLANDY, JOHN F.

The lake Superior Copper Rocks in Pennsylvania. Trans. Am. Inst. Min. Eng., 1879, vii., 331–333, 336.

CHAMBERLIN, T. C.

Geology of Wisconsin. 1873–79, iii., 763 pp., with maps. Reports by Messrs. R. D. Irving, R. Pumpelly, A. A. Julien, C. E. Wright, E. T. Sweet, T. B. Brooks, A. Wichmann, T. C. Chamberlin, and T. S. Hunt.

CROSBY, WILLIAM O.

On a Possible Origin of Petrosiliceous Rocks. Proc. Bost. Soc. Nat. Hist., 1879, xx., 160–169.

Evidences of Compression in the Rocks of the Boston Basin. Ibid., xx., pp. 308–313.

DANA, J. D.

On the Hudson River Age of the Taconic Schists, and on the Dependent Relations of the Dutchess County and Western Conn. Limestone Belts. Am. J. Sci., 3d series. Vol. 17, 375–388; Vol. 18, pp. 61–64.

FRAZER, PERSIFOR, Jr.

The lake Superior Copper Rocks in Pennsylvania. Trans. Am. Inst. Min. Eng., 1879, vii., 336–339.

HALL, CHARLES E.

Laurentian Magnetic Iron Ore Deposits of Northern New York, accompanied by a geological map of Essex county. Report of the State Geologist of N. Y., 1884, pp. 23–34. With a supplementary note dated December, 1884.

HUNT, T. STERRY.

The lake Superior Copper Rocks in Pennsylvania. Trans. Am. Inst. Min. Eng., 1879, vii., 333–336, 339.

The History of some Pre-Cambrian Rocks in Europe and America. Am. Jour. Sci., Vol. 19, pp. 268–283; A. A. A. S., Vol. 28, pp. 279–296.

IRVING, ROLAND D.

Note on the Stratigraphy of the Huronian Series of Northern Wisconsin; and on the Equivalency of the Huronian of the Marquette and Penokee Districts. Am. Jour. Sci., 1879 (3), xvii., 393–398.

MACFARLANE, THOMAS.

Remarks on Canadian Stratigraphy. Canadian Nat. and Geol., 1879 (2), ix., 91–102.

MOSLER, CHR.

Der Kupferbergbau am Obern See in Nordamerika. Zeitschr. Berg. Hütt. Salin., 1877, Abhandlungen, xxv., 203–221; 1879, xxvii., 77–97.

SHALER, N. S.

Notes on Certain Evidences of a Gradual Passage from Sedimentary to Volcanic Rocks shown in the Brighton District of Boston. Proc. Boston Soc. Nat. Hist., Vol. 20, pp. 129–133.

WICHMANN, ARTHUR.

A Microscopical Study of some Huronian Clay Slates. Quart. Jour. Geol. Soc., 1879, xxxv., 156–164.

WINCHELL, N. H.

Seventh Annual Report on the Geol. and Nat. Hist. Sur. of Minnesota. Has a general account of the Mining Geology of the region of lake Superior in Minnesota, and a field report by C. W. Hall.

1880.

BAILEY, L. W.

On the progress of Geological Investigation in New Brunswick, 1870–1880. Proc. Am. Assoc. Ad. Sci., Vol. XXIX., pp. 415–421.

BAILEY, L. W., G. F. MATTHEW, and R. W. ELLS.

Report on Geology of Southern New Brunswick, embracing the counties of Charlotte, Sunbury, Queens, Kings, St John and Albert. Geol. Survey of Canada. Reports for 1878-79, D, pp. 1–26.

BELL, ROBERT.

Report on Explorations on the Churchill and Nelson rivers and around God's and Island lakes, 1879. Geol. Survey of Canada for 1878–79, C, pp. 1–72.

BENTON, E. R.

The Amygdaloidal Melaphyr of Brighton, Mass. Proc. Boston Soc. Nat. History, Vol. 20, pp. 416–426.

BROOKS, T. B.

Geology of the Menominee region. Geol. of Wisconsin, Vol. III., Part 7, pp. 430–599.

CHAMBERLIN, T. C.

Geology of the Upper St. Croix District; based on the notes of the late Moses Strong. Geol. of Wisc., Vol. 3, Part 6, pp. 365–428.

CROSBY, W. O.

Distorted Pebbles in Conglomerate. Proc. Bost. Soc. Nat. Hist., Vol. 20, pp. 368–378.

Contributions to the Geology of Eastern Massachusetts. Occasional Papers. Boston Soc. Nat. Hist. (3), 286 pp., with map.

Geology of Frenchman's Bay, Maine. Bost. Soc. Nat. Hist. Proc., Vol. 21, pp. 109–117.

DANA, J. D.

On the Geological Relation of the Limestone Belts of Westchester County, New York. Am. Jour. Sc., Vol. 20, pp. 26–32, 194–220, 359–375, 450–456; Vol. 21, pp. 425–443; Vol. 22, pp. 103–119, 313–315, 327–335.

List of Papers on the Taconic System. Am. Jour. Sc., Vol. 19, pp. 153–155.

DAVIS, W. M.

Banded Amygdules of the Brighton Amygdaloid. Proc. Bost. Soc. Nat. Hist., xx., pp. 426–28.

DAVIS, D. C.

Metalliferous Minerals and Mining. London. 432 pp.; copper rocks, pp. 149–164; iron ores, pp. 274–275.

DILLER, J. S.

Felsites and their Associated Rocks North of Boston. Bost. Soc. Nat. Hist. Proc., Vol. 20, pp. 355–368.

FORD, S. W.

Note on the Trilobite, Atops Trilineatus of Emmons. Am. Jour. Sci., iii., Vol. 19, p. 152.

On the Western Limits of the Taconic System. Am. Jour. Sci., iii., pp. 225–226.

GEIKIE, ARCHIBALD.

On the Archæan Rocks of the Wahsatch Mountains. Am. Jour. Sci., iii., Vol. 19, pp. 363–367.

HALL, C. W.

Report of Prof. C. W. Hall. Geol. and Nat. Hist. Survey of Minn., 8th Annual Report, for 1879, pp. 126–138.

HUNT, T. STERRY.

The History of some Pre-Cambrian Rocks in America and Europe. Am. Jour. Sci., iii., Vol. 19, pp. 268–283.

Letters and Notes on the Iron-bearing and Associated Rocks of the Marquette Region, and Comparisons with the Archæan of Canada and Eastern United States. Geol. of Wisc., Vol. 3, Part 7, pp. 657–660.

IRVING, R. D.

General Geology of the lake Superior Region. Geology of Wisc., Vol. 3, Part 7, pp. 1–24.

Geology of the Eastern lake Superior District. Geology of Wisc., Vol. 3, Part 3, pp. 53–223.

JULIEN, A. A.

Microscopial Examination of Eleven Rocks from Ashland Co., Wisc. Geol, of Wisc., Vol. 3, pp. 224–238.

MARCOU, JULES.

Sur les Colonies dans les Roches Taconiques des Bords du lac Champlain. Bull. Soc. Geol. de France, iii., Tome 9, p. 18.

NEWBERRY, J. S.

The Genesis of Our Iron Ores. School of Mines Quart., November, pp. 1–17.

PEACH and JOHN HORNE.

The Old Red Sandstone of Orkney. Roy. Phys. Soc., April.

PECKHAM, S. F., and HALL, C. W.

On Lintonite and other forms of Thomsonite: A preliminary notice of the zeolites of the vicinity of Grand Marais, Minn. Am. Jour. Sci., iii, Vol. 19, pp. 122–130. Geol. and Nat. Hist. Survey of Minn. 8th Annual Report, for 1879, pp. 166–172.

PUMPELLY, RAPHAEL.

Lithology of the Keweenawan or Copper-bearing System. Geol. of Wisc., Vol. 3, pp. 27–49.

SWEET, E. T.

Geology of Western lake Superior District. Geol. of Wisc., Vol. 3, pp. 305–362.

UPHAM, WARREN.

Preliminary report on the Geology of Central and Western Minnesota. Geol. and Nat. Hist. Survey of Minn., 8th Annual Report, for 1879, pp. 97–103.

WADSWORTH, M. E.

Notes on the Geology of the Iron and Copper Districts of lake Superior. Bulletin Mus. Comp. Zool., Vol. 7 (Geol. Series, Vol. 7), pp. 1–164.

On the Origin of the Iron Ores of the Marquette District, lake Superior. Bost. Soc. Nat. Hist. Proc., Vol. 20, pp. 470–479.

On the Filling of Amygdaloidal Cavities and Veins in the Keweenaw Point District of lake Superior. A reply to Prof. James D. Dana. Bost. Soc. Nat. Hist. Proc., Vol. 21, pp. 91–103.

On the Age of the Copper-bearing Rocks of lake Superior. (Abstract.) Am. Assoc. Adv. Sci. Proc., Vol. 29, pp. 429–430.

WHITNEY, J. D., and WADSWORTH, M. E.

Azoic System and its Proposed Sub-divisions. Bull. Mus. Comp. Zool., Vol 7 (Geol. Series, Vol. 1), pp. 331–565.

WICHMANN, Dr. ARTHUR.

Microscopical Investigations of Huronian Rocks from the Iron-region of lake Superior. Geol. of Wisc., Vol. 3, pp. 600–656.

WINCHELL, N. H.

The Cupriferous Series at Duluth. Geol. and Nat. Hist. Survey of Minn· 8th Annual Report for 1879, pp. 22–26.

The Cupriferous Series in Minnesota. Am. Assoc. Adv. Sci. Proc., Vol. 29, pp. 422–425. Geol. and Nat. Hist. Survey of Minn., Annual Report for 1880, pp. 385–387.

WRIGHT, C. E.

Huronian Series west of Penokee Gap. Geol. of Wisc., Vol. 3, pp. 241–301.

Geology of the Menominee Iron-region. (Economic resources, Lithology and Westerly and Southerly extensions.) Geol. of Wisc., Vol. III., pp. 666–734.

1881.

CROSBY, W. O.

On the absence of Joint-structure at great depths, and its relations to the forms of coarsely Crystalline Eruptive masses. Geol. Mag. Decade 11, Vol. VIII.

On the Age and Succession of the Crystalline Formations of Guiana and Brazil. Proc. Bost. Soc. Nat. Hist., Vol. XX., pp. 480–497.

DAWSON, GEO. M.

Sketch of the Geology of British Columbia. Geol. Soc. of London, Proc.

ELLS, R. W.

Report on Northern New Brunswick. Geol. Survey of Canada, Report of Progress for 1879–80, D, pp. 1–47.

FLETCHER, HUGH.

Report of Surveys in Richmond, Inverness, Guesboro and Antigonish, Nova Scotia. Geol. Survey of Canada, Report of Progress for 1879–80, F, pp. 1–125.

FORD, S. W.

Remarks on the genus Obolella. Am. Jour. Sci., iii., Vol. 21, pp. 132–134.

On Additional Embryonic Forms of Trilobites from the Primordial Rocks of Troy, N. Y., with Observations on the Genera Olenellus, Paradoxides and Hydrocephalus. Am. Jour. Sci., iii., Vol. 22, pp. 250–259.

HAWES, GEO. W.

The Albany Granite, New Hampshire, and its contact phenomena. Am. Jour. Sci., iii., Vol. 21, pp. 21–32.

HUNT, T. STERRY.

The Taconic System in Geology. Am. Nat., Vol. 15, pp. 494–496.

MARCOU, JULES.

The Taconic Rocks of the Border of lake Champlain. Geol. Soc. of France, Bulletin (3), Vol. 9, No. 1.

MERRILL, N. F.

Concerning the Lithological Collection of the Exploration of the Fortieth Parallel. Proc. Boston Soc. Nat. Hist., Vol. 21, pp. 234-242.

NEWTON, HENRY, and JENNEY, WALTER P.

Report on the Geology and Resources of the Black Hills of Dakota. U. S. Geog. and Geol. Survey of the Rocky Mountain Region, J. W. Powell, 566 pp.

ROMINGER, C.

Upper Peninsula. Geol. Survey of Mich., Vol. 4, pp. 1-241.

WADSWORTH, M. E.

On the Trachyte of Marblehead Neck, Massachusetts. Bost. Soc. Nat. Hist. Proc., Vol. 21, pp. 288-294.

A Microscopic Study of the Cumberland Iron Ore, of Rhode Island. (Abstract.) Ibid., pp. 194-197.

Some Points Relating to the Geological Exploration of the Fortieth Parallel. Ibid., pp. 243-274.

On the Relation of the Quincy Granite to the Primordial Argillite of Braintree, Massachusetts. Ibid., pp. 274-277.

WINCHELL, N. H.

Preliminary List of Rocks. Geol. and Nat. Hist. Survey of Minn. Annual Report for 1880, pp. 10-114.

Typical Thin Sections of the Rocks of the Cupriferous Series in Minnesota. Am. Assoc. Adv. Sci. Proc., Vol. 30, pp. 160-166. Geol. and Nat. Hist. Survey of Minn. 10th Annual Report for 1881, pp. 137-143.

YOUNG, A. A.

On Sandstones having the Grains in part Quartz Crystals. Am. Jour. Sci. iii., Vol. 23, p. 257.

1882.

CROSBY, W. O.

On the Classification and Origin of Joint Structures. Bos. Soc. Nat. Hist. Proc., Vol. XXIII., pp. 72-85.

DANA, J. D.

Geological Age of the Taconic System. Quart. Journal Geol. Soc., Vol. 38, p. 392. Am. Jour. Sci. iii., Vol. 24, pp. 291-293. (Abstract.)

DAVIS, WILLIAM MORRIS.

The Structural Value of the Trap Ridges of the Connecticut Valley. Proc. Boston Soc. Nat. Hist., Vol. 22, pp. 116-124.

DWIGHT, W. B.

Recent Investigations and Palæontological Discoveries in the Wappinger Limestone of Dutchess and Neighboring Counties, N. Y. A. A. A. S., Vol. 31, pp. 384-387.

FRAZER, PERSIFOR.

Mémoire sur la geologie de la partie sud-est de la Pennsylvanie. Thèses présentées a la Faculté des Sciences de Lille Université de France. 179 pp.

The Horizon of the South Valley Hill Rocks in Pennsylvania. Am. Phil. Soc., Dec., pp. 510–518.

The Eozoic and Lower Paleozoic in South Wales and their Comparison with their Appalachian Analogues. Am. Inst. Min. Eng., Feb.

JACKSON, A. W.

On the General Principle of the Nomenclature of the Massive Crystalline Rocks. Am. J. Sci., 3d Series, Vol. 24, pp. 113–129.

JULIEN, A. A.

The Dunyte Beds of North Carolina. Bost. Soc. Nat. Hist. Proc., Vol. 22, pp. 141–149.

The Genesis of the Crystalline Iron Ores of North Carolina and Northern Michigan. Bost. Soc. Nat. Hist., Vol. 22.

The Genesis of the Crystalline Iron Ores. Acad. Nat. Sci. Phil. Proc., Vol. —, pp. 335–346.

MERRILL, N. F.

Concerning the Lithological Collection of the Exploration of the Fortieth Parallel. (Second Paper.) Proc. Boston Soc. Nat. Hist., Vol. 21, pp. 452–470.

SELWYN, A. R. C.

The Quebec Group in Geology. Roy. Soc. Canada, Vol. I., Sec. IV., pp. 1–15.

WADSWORTH, M. E.

The Argillite and Conglomerate of the Boston Basin. Proc. Bost. Soc. Nat. Hist., Vol. XXII., November.

On the Relations of the so-called Felsite to the Conglomerate on Central Avenue, Milton, Mass. Harv. Univ. Bul., 1882, II., pp. 431, 432.

WINCHELL, N. H.

Preliminary List of Rocks Collected in 1879. Geol. and Nat. Hist. Survey of Minn. 10th Annual Report, pp. 9–122.

The Potsdam Sandstone, *l. c.*, pp. 123–136.

Geological Notes on Minnesota, by J. H. Kloos. Translated by N. H. Winchell, *l. c.* pp. 175–200.

YOUNG, A. A.

Further Observations on the Crystallized Sands of the Potsdam Sandstone of Wisconsin. Am. Jour. Sci. iii., Vol. 24, pp. 47–49.

ZIRKEL, Dr. F.

Some Remarks upon the Petrographical Collection of the Geological Exploration of the Fortieth Parallel. Proc. Boston Soc. Nat. Hist., Vol. 22, pp. 109–116.

1883.

ADAMS, FRANK D.

Notes on the Microscopic Structure of some Rocks of the Quebec Group. Geol. Survey of Canada. Reports of Explorations and Surveys for 1880–81–82, A, pp. 8–23.

BELL, ROBERT.

On the Geology of the basin of Moose river and of the Lake of the Woods and adjacent country, 1881. Geol. Survey of Canada. Reports of Explorations and Surveys for 1880–81–82, C, pp. 1–39.

CHAMBERLIN, T. C.

The Copper-bearing Series of lake Superior. Science, Vol. 7, p. 453.

General Geology (of Wisconsin). Geol. of Wisc., Vol. 1, Part I., pp. 3–300.

COOK, GEO. H.

Archæan Rocks and Iron Ores. Geol. Survey of New Jersey. Annual Report for 1883, pp. 27–77.

DAWSON, GEO. M.

"The Quebec Group." Appendix to Notes by A. R. C. Selwyn on the life of Sir W. Logan, by B. J. Harrington.

DALE, T. NELSON.

A Contribution to the Geology of Rhode Island. (Contains a Bibliography.) Proc. Boston Soc. Nat. Hist., Vol. 22, pp. 179–201.

ELLS, R. W.

Report on Northern and Eastern New Brunswick and North Side of the Bay of Chaleurs. Geol. Survey of Canada. Reports of Explorations and Surveys, 1880–81–82, D, pp. 1–24.

Report on the Geological Formations in the Gaspé Peninsula, 1882, *l. c.*, DD., pp. 1–32.

HALL, JAMES (State Geologist).

Field Notes on the Geology of the Mohawk Valley, with a map. Fifth Report of the State Geologist, pp. 8–10. Albany.

HONEYMAN, D.

Nova Scotian Geology; Halifax and Colchester counties, 16 pp.

HUNT, T. STERRY.

The Geology of lake Superior. Science, Vol. 7, p. 218.

The Geological History of Serpentines, including Notes on Pre-Cambrian Rocks. Trans. Roy. Soc., Canada, Vol. 7, Sec. 4, pp. 165–215.

A Historical Account of the Taconic Question in Geology, with a Discussion of the Relations of the Taconian Series to the Older Crystalline, and to the Cambrian Rocks. Trans. Roy. Soc., Canada, Vol. 1, Part 4, pp. 217–270, and Vol. 2, Part 2, pp. 125–157.

IRVING, R. D.

On the Nature of the Induration in the St. Peter's and Potsdam Sandstones, and certain Archæan Quartzytes, in Wisconsin. Am. Jour. Sci., iii., Vol. 25, pp. 401–411.

The Copper-bearing Rocks of lake Superior. 3d Annual Report of the U. S. Geol. Survey, 1881–82, pp. 93–188.

The Copper-bearing Rocks of lake Superior. Science, Vol. 1, 140, 359 and 422.

On the Paramorphic Origin of the Hornblende of the Crystalline Rocks of the Northwestern States. Am. Jour. Sci., Vol. 27, pp. 27–32 and 321.

Lithology of Wisconsin. Geology of Wisc., Vol. 1, Part 2, pp. 340–361.

Copper-bearing Rocks of lake Superior. Mon. V., U. S. Geol. Surv.

LE CONTE, JOSEPH.

On the Genesis of Metalliferous Veins. Am. Jour. Sci., 1883, Vol. XXVI., July.

Mineral Vein Formation Now in Progress at Steamboat Springs, compared with the same at Sulphur bank. Am. Jour. Sci., Vol. 25, 1883, June.

MATTHEW, G. F.

Illustrations of the Fauna of the St. John Group. Trans. Roy. Soc., Canada, Vol. 1, Sect. 4, pp. 87–108 and 271–279.

SALISBURY, R. D.

Chemical Analyses Geol. Wisc., Vol. I., Part 2, pp. 303–308.

SELWYN, A. R. C.

The Quebec Group in Geology. Science, Vol. IX., p. 267.

On the Geology of lake Superior. Trans. Roy. Soc. Canada, Vol. 1, Sec. 4, pp. 117–122.

Age of the Rocks of the Northern Shore of lake Superior. Science, Vol. I, p. 11.

The Copper-bearing Rocks of lake Superior. Science, Vol. I, p. 221.

Notes on the Geology of the Southeastern Portion of the Province of Quebec. Geol. Survey of Canada, Reports of Explorations and Surveys, 1880–81–82, A, pp. 1–23.

Notes on the Life of Sir W. E. Logan by B. J. Harrington, with an Appendix on "The Quebec Group," by Principal Dawson, pp. 8.

WADSWORTH, M. E.

The Fortieth Parallel Rocks. Proc. Boston Soc. Nat. Hist., Vol. 22, pp. 412–432.

WALCOTT, C. D.

The Cambrian System in the United States and Canada. Phil. Soc. Washington, Vol. 6, pp. 98–102.

WINCHELL, N. H.

The Lake Superior Rocks. Science, Vol. I, p. 334.

1884.

BAILEY, L. W.

Report of Explorations and Surveys in portions of York and Carleton Counties, New Brunswick. Geol. Survey of Canada. Report of Progress for 1882–83–84, G, pp. 1–31.

BAUERMAN, H.

Report on the Geology of the Country near the 49th Parallel of North Latitude, west of the Rocky Mountains. Geol. Survey of Canada. Report of Progress for 1882-83-84, B, pp. 1-42.

BELL, ROBERT.

Observations on the Geology, Mineralogy, Zoology and Botany of the Labrador Coast Hudson's Strait and Bay. Geol. Survey of Canada. Report of Progress for 1882-83-84, DD, pp. 1-62.

CHAMBERLIN, T. C.

Geology of Wisconsin. Survey of 1873-1879. Vols. 1 and 2. Am. Jour., Sci., iii., Vol. 27, 146.

CHESTER, ALBERT H.

The Iron Region of Northern Minnesota. 11th Annual Report of the Geol and Nat. Hist. Survey of Minn., pp. 154-167.

CHESTER, F. D.

Preliminary Notes on the Geology of Delaware Laurentian, Palæozoic and Cretaceous Areas. Proc. Acad. Nat. Sci. Philadelphia, 1884, pp. 237-259.

COOK, GEO. H.

Archæan Rocks. Geol. Survey of New Jersey. Annual Report for 1884, pp. 57-69.

COSTE, EUGENE.

Report on the Gold Mines of the Lake of the Woods. Report of Progress of the Geol. Surv. of Canada for 1882-83-84, K, pp. 1-22.

CROSBY, W. O.

On the Relations of the Conglomerate and Slate in the Boston Basin. Boston Soc. Nat. Hist. Proc., Vol. 23, pp. 7-27.

DANA, J. D.

On the Southward Ending of a Great Synclinal in the Taconic Range. Am. Jour. Sci., iii., Vol. 28, pp. 268-275.

Professor James Hall on the "Hudson River"—Age of the Taconic Slates. Am. Jour. Sci., iii., Vol. 28, p. 311.

Note on the Cortlandt and Stony Point Hornblendic and Augitic Rocks. Am. Jour. Sci., iii., Vol. 28, pp. 384-386.

Note on the Origin of Bedding in the so-called Metamorphic Rocks. Am. Jour. Sci., iii., Vol. 28, pp. 393-396.

DICKERMAN, Q. E., and WADSWORTH, M. E.

An Olivine-bearing Diabase, from St. George, Maine. Proc. Boston Soc. Nat. Hist., Vol. 23, pp. 28, 29.

ELLS, R. W.

Report on Explorations and Surveys in the Interior of the Gaspé Peninsula, 1883. Report of Progress of the Geol. Survey of Canada, 1882-83-84, E, pp. 1-34.

FLETCHER, HUGH.

Report on the Geology of Northern Cape Breton. Report of Progress of the Geol. Surv. of Canada, 1882-83-84, H, pp. 1-98.

FORD, S. W.

Note on the Discovery of Primordial Fossils in the Town of Stuyvesant, Columbia Co., N. Y. Am. Jour. Sci., iii., Vol. 28, pp. 35–37.

On the Age of the Glazed and Contorted Slate Rocks in the Vicinity of Schodack Landing, Rensselaer Co., N. Y. Am. Jour. Sci., iii., Vol. 28, pp. 206–208.

FRAZER, PERSIFOR.

Archæan-Palæozoic Contact near Philadelphia, Pa. Am. Assoc. Adv. Sci. Proc., Vol. 33, pp. 1–5.

HITCHCOCK, C. H.

Descriptions of Geological Sections crossing New Hampshire and Vermont. 33 pp., Am. Mus. Nat. Hist. Bul. No. 5.

Identification of the Green Mountain Gneisses in New England. (Abstract.) A. A. A. S., Vol. 33, pp. 396–397.

HUNT, T. STERRY.

The Genesis of the Crystalline Rocks. Am. Nat., Vol. 18, pp. 605–607.

The Origin of Crystalline Rocks. Trans. Roy. Soc. Canada, Vol. 2, Sec. III, pp. 1–67. Am. Jour. Sci., iii., Vol. 28, pp. 72–74. (Abstract.)

IRVING, R. D.

The Copper-bearing Rocks of lake Superior. U. S. Geol. Survey, Monographs, Vol. 5, 464 pp.

Note on the Paramorphic Origin of the Hornblende of the Crystalline Rocks of the Northwest. Am. Jour. Sci., iii., Vol. 28, p. 464.

Supplement to the paper on Paramorphic Origin of the Hornblende of the Crystalline Rocks of the Northwestern States. Am. Jour. Sci., iii., Vol. 27, pp. 130–134.

IRVING, R. D., and VAN HISE, C. R.

On Secondary Enlargements of Mineral Fragments in certain rocks. U. S. Geol. Survey, Bulletin No. 8.

JULIEN, A. A.

Genesis of the Crystalline Iron Ores. Engin. and Mining Jour. Feb. 2, 1884.

KIMBALL, JAS. P.

Geological Relations and Genesis of the Specular Iron Ores of Santiago de Cuba. Am. Jour. Sci., iii., Vol. 28, pp. 416–429.

The Iron Ore Range of the Santiago District of Cuba. Trans. Am. Inst. Min. Eng., pp. 22.

LAFLAMME, ABBÉ J. C. K.

Report of Geological Observations in the Saguenay Region. Report of Progress of the Geol. Surv. of Canada, 1882–83–84, D, pp. 1–18.

On Strain in Connection with Crystallization and the Development of Perlitic Structure. Quart. Jour. Geol. Soc., Aug., 1884, p. 340.

LOW, A. P.

Report on Explorations and Surveys in the Interior of the Gaspé Peninsula, 1883. Report of Progress of the Geol. Surv. of Canada, 1882–83–84, F, pp. 1-21.

MATTHEW, G. J.

Fauna of the St. John Group, New Brunswick. Trans. Roy. Soc., Canada, Vol. 2, Sect. 4, pp. 99–124.

RUTLEY, F.

The Vitreous Rocks of Montana. Quart. Jour. Geol. Soc., Vol. XXXVII., p. 391.

SELWYN, A. R. C.

Notes on Observations, 1883, on the Geology of the North Shore of lake Superior. Trans, Roy. Soc., Canada, Vol. 2, Sect. 4, p. 245.

Report on the Geological and Natural History Survey of Canada for 1880–81–82.

STEVENSON, JOHN J.

Some Notes Respecting Metamorphism. Am. Phil. Soc., 1884, pp. 161–66.

UPHAM, WARREN.

Notes on Rock-outcrops in Central Minnesota. Annual Report of the Geol. and Nat. Hist. Surv. of Minn., 11th, pp. 86–136.

VAN HISE, C. R.

On Secondary Enlargements of Feldspar-fragments in certain Keweenawan Sandstones. Am. Jour. Sci., iii., Vol. 27, pp. 399–403.

VENNOR, H. G.

Calcium Phosphate, or Apatite, of the Canadian Rocks. Canadian Mining Review, January, 1884.

WADSWORTH, M. E.

Lithological Studies. Mem. Mus. Comp. Zool. Cambridge. Vol. IX., Part I., pp. 210, 4to. On the Relation of the "Keweenawan Series" to the Eastern Sandstone in the Vicinity of Torch Lake, Mich. Proc. Boston Soc. Nat. History, Vol. 23, pp. 172–180.

The Theories of Ore Deposits. Ibid., pp. 197–208.

On a Supposed Fossil from the Copper-bearing Rocks of lake Superior. Ibid., pp. 208–212.

WALCOTT, C. D.

Note on Paleozoic Rocks of Central Texas. Am. Jour. Sci., iii., Vol. 28, pp. 431–433, figure of section.

WHITFIELD, R. P.

Notice of some New Species of Primordial Fossils and Correction of previously described Species. Am. Mus. Nat. Hist. Bul. No. 5, p. 140.

Palæontological Similarity of the East American Acadian and Potsdam Groups. Am. Jour. Sci., iii., Vol. 27, p. 321. Am. Mus. Bulletin 5, New York.

WHITNEY, J. D., and WADSWORTH, M. E.

The Azoic System and its Proposed Sub-divisions. Mus. Comp. Zool. Bulletin XI., Vol. 7 (Geol. Series 1), pp. 331–566.

WILLIAMS, G. H.

Origin of Crystalline Schists, by J. Lehmann (Abstract.) A. A. A. S., Vol. 33, pp. 405-407.

WILLIAMS, GEO. H.

On the Paramorphosis of Pyroxene to Hornblende in Rocks. Am. Jour. Sci., iii., Vol. 28, pp. 259-268.

WINCHELL, N. H.

The Crystalline Rocks of Minnesota, by A. Streng and J. H. Kloos. Translated by N. H. Winchell. Geol. and Nat. Hist. Sur. of Minn., 11th Annual Report for 1882, pp. 30-85.

Note on the Age of the Rocks of the Mesabi and Vermilion Iron District. *l. c.*, pp. 168-170.

The Comparative Strength of Minnesota and New England Granites. Geol. and Nat. Hist. Surv. of Minn. 12th Annual Report, 1883, pp. 14-18.

The Crystalline Rocks of the Northwest. Am. Nat., October, 1884, pp. 984-1000. Am. Assoc. Adv. Sci. Proc., Vol. 33, pp. 363-379.

The Mineralogy of Minnesota. 10th Annual Report on the Geology of Minnesota, pp. 5-29.

and WARREN UPHAM.

Geological and Natural History Survey of Minnesota. Final Report, Vol. I.

WOOSTER, L. C.

Transition from the Copper-bearing Series to the Potsdam. Am. Jour. Sci., iii., Vol. 27, pp. 463-465.

1885.

BROADHEAD, G. C.

Sketch of the Geology of Missouri. Missouri Agl. Report, pp. 250-259.

CHESTER, F. D.

Results from a study of the Gabbros and Associated Amphibolites in Delaware. (Abstract.) A. A. A. S., Vol. 34, pp. 215-216.

COOK, GEO. H.

Archæan Rocks, Geol. Survey of New Jersey. Annual Report for 1885, pp. 36-55.

DANA, J. D.

On Taconic Rocks and Stratigraphy, with a geological map of the Taconic region. Am. Jour. Sci., iii., Vol. 29, pp. 205-222, 437-443; Vol. 33, pp. 270-276, 393-412.

On Displacement through Intrusion. Am. Jour. Sci., Vol. XXX., p. 374.

ELLS, R. W.

On the Geological Formations of Eastern Albert and Westmoreland Counties, New Brunswick, and of portions of Cumberland and Colchester Counties, Nova Scotia. Geol. and Nat. Hist. Survey of Canada, New Series, Vol. 1, E, pp. 1-71.

FORD, S. W.

Note on the Age of the Slaty and Arenaceous Rocks in the vicinity of Schenectady, Schenectady County, N. Y. Am. Jour. Sci., iii., Vol. 29, pp. 397-398.

Observations upon the Great Fault in the vicinity of Schodack Landing, Rensselær County, N. Y. Am. Jour. Sci., iii., Vol. 29, pp. 16-19.

FRAZER, PERSIFOR.

General Notes. Sketch on the Geology of York County, Pennsylvania. Am. Phil. Soc. Proc., December, 1885, pp. 391–410.

HITCHCOCK, C. H.

The Crystalline Rocks of Alabama. Am. J. Sci., 3d Series, Vol. 30, pp. 278–283.

IRVING, R. D.

Divisability of the Archæan in the Northwest. Am. Jour. Sci., iii., Vol. 29, pp. 237–249.

Preliminary Paper on an Investigation of the Archæan Formations of the Northwestern States. 5th Annual Report of the U. S. Geol. Surv., 1883–4, pp. 181–242.

IRVING, R. D., and CHAMBERLIN, T. C.

Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on the Keweenaw Point, lake Superior. Bulletin U. S. Geol. Survey, No. 23. Reviewed in Am. Geol., Vol. 1, pp 44–57.

LAWSON, A. C.

Report on the Geology of the Lake of the Woods Region, with Special Reference to the Keewatin (Huronian?) Belt of the Archæan Rocks. Geol. and Nat. Hist. Survey of Canada, Vol. 1, n. s., CC., pp. 1–151.

MARCOU, JULES.

The Taconic System and its Position in Stratigraphical Geology. Am. Acad. Sci. Proc., Vol. 12, pp. 174–256.

MATTHEW, GEO. F.

Probable Occurrence of the Great Welsh Paradoxides, P. davidis, in America. Am. Jour. Sci., Vol. XXX., p. 72.

Recent Discoveries in the St. John Group. Can. Rec. Sci., Vol. 1, pp. 136–141.

Notice of a New Genus of Pteropods from the St. John Group (Cambrian). Am. Jour. Sci., Vol. XXX., p. 293.

PENFIELD, SAMUEL L.

Crystals of Analcite from the Phœnix Mine, lake Superior Copper Region. Am. Jour. Sci., iii., Vol. 30, pp. 112–113.

SELWYN, A. R. C.

Report of Progress of the Geological and Natural History Survey of Canada during the years 1882–83–84.

TAYLOR, W. B.

On the Crumpling of the Earth's Crust. Am. Jour. Sci., Vol. XXX., pp. 249–266.

TODD, JAMES E.

Description of some Fossil Tracks from the Potsdam Sandstone. Wis. Acad. Sciences, Arts and Letters, Vol. V., pp. 276–281.

UPHAM, WARREN.

Notes on the Geology of Minnehaha County, Dakota. 13th Annual Report of Geol. and Nat. Hist. Survey of Minn. for 1884, pp. 88–97.

VAN HISE, C. R.

Enlargements of Hornblende Fragments. Am. Jour. Sci., iii., Vol. 30, pp. 231–235.

WADSWORTH, M. E.

On the Presence of Syenite and Gabbro in Essex County, Massachusetts. Geol. Magazine, Decade III., Vol. II., p. 207.

WALCOTT, C. D.

Palæontologic Notes. Am. Jour. Sci., Vol. XXIX., February.

Palæozoic Notes. New Genus of Cambrian Trilobites. Am. Jour. Sci., Vol. XXIX., April.

Note on some Palæozoic Pteropods. Am. Jour. Sci., Vol. XXX., July.

Bulletin No. 10, U. S. Geological Survey. On the Cambrian Faunas of North America. 55 pp., 10 plates, 91 figures.

Monograph VIII., U. S. Geological Survey. Palæontology of the Eureka District. pp. 298, 24 plates, 570 figures.

WINCHELL, N. H.

The Geological and Natural History Survey of Minnesota. 13th Annual Report for the Year 1884. Contains: Notes of a Trip Across the Mesabi Range to Vermilion Lake; The Vermilion Iron Ores; Fossils from the Red Quartzyte at Pipestone; The Crystalline Rocks of the Northwest.

WINCHELL, ALEXANDER.

Sources of Trend and Crustal Surplusage in Mountain Structure. Am. Jour. Sci., Vol. XXX., p. 417. A. A. A. S. Ann Arbor Meeting, Vol. XXXIV., pp. 209–212.

1886.

BAILEY, L. W.

Explorations and Surveys in Portions of the Counties of Carleton, Victoria, York, and Northumberland, N. B. Annual Report of the Geol. Survey of Canada, Vol. 1, N. S. G., pp. 29 and map.

Geology and Geologists in New Brunswick. Canadian Rec. Sci., Vol. 2, pp. 93–96.

BELL, ROBERT.

The Mineral Resources of the Hudson Bay Territories. Am. Inst. Mining Eng. Trans., Vol. 15, p. 9.

The Mode of Occurrence of Apatite in Canada. Canadian Inst. Proc., Vol. 21, pp. 294–302.

Observations on the Geology, Zoology, and Botany of Hudson Strait and Bay. Annual Report Geol. Survey of Canada, Vol. 1, n. s. DD, pp. 26.

BRITTAN, N. L.

Reports on the Study of the Archæan Rocks of New Jersey. Annual Report of the State Geologist of N. J. for 1885, pp. 36–55.

CHAPMAN, E. J.

On the Wallbridge Hematite Mine, as Illustrating the Stock-formed Mode of Occurrence of Certain Ore Deposits. Roy. Soc. Canada, Proc., Vol. 3, Sect. 4, pp. 23–26.

CHESTER, FRED D.

Results from a Study of the Gabbros and Associated Amphibolites in Delaware. Am. Assoc. Adv. Sci. Proc., Vol. 34, pp. 215–216.

CROSBY, W. O., and BARTON, G. H.

On the Great Dikes at Paradise, near Newport, R. I. Proc. Boston Soc. Nat. History, Vol. 23, pp. 325–330.

DANA, J. D.

On the Lower Silurian Fossils from a Limestone of the Original Taconic of Emmons. Am. Jour. Sci., iii., Vol 31, pp. 241–248.

The History of Taconic Investigation previous to the Work of Professor Emmons. Am. Jour. Sci., iii., Vol. 31, pp. 399–400.

The Taconic Stratigraphy and Fossils. Am. Jour. Sci., iii., Vol. 32, pp. 236–239.

DARTON, N. H.

The Taconic Controversy in a Nutshell. Science, Vol. 7, pp. 78–79.

DAWSON, J. W.

Geology of the Canadian Pacific Railway. Quart. Jour. Geol. Soc., Vol. XL., p. 370.

DILLER, J. S.

Peridotite of Elliott County, Kentucky. Bul. U. S. Geological Survey, No. 38.

EMERSON, B. K.

Preliminary Note on the Succession of the Crystalline Rocks and their Various Degrees of Metamorphism in the Connecticut River Region. Proc. Am. Assoc. Adv. Sci., Vol. 35, p. 231.

FORD, S. W., and W. B. DWIGHT.

Preliminary Report upon the Fossils obtained in 1885 from Metamorphic Limestone of the Taconic Series of Emmons, at Canaan, N. Y. Am. Jour. Sci., iii., Vol. 31, pp. 248–255.

HERRICK, C. L., TIGHT, and H. L. JONES.

Geology and Lithology of Michipicoten Bay. Bul. of Denison University, Vol. II., pp. 120–144. Pls. X., XI., XII.

HUNT, T. STERRY.

Mineral Physiology and Physiography. A second series of Chemical and Geological Essays. 710 pp. Boston.

IRVING, R. D.

Origin of the Ferruginous Schists and Iron Ores of the lake Superior Region. Am. Jour. Sci., iii., Vol. 32, pp. 255–272.

LAWSON, A. C.

Some Instances of Gneissic Foliation and Schistose Cleavage in Dikes and their Bearing upon the Problem of the Origin of the Archæan Rocks. Canadian Inst. Proc., Vol. 32, pp. 115–128.

MARCOU, JULES.

On the Use of the Name Taconic. (Contains Bibliography.) Bost. Soc. Nat. Hist. Proc., Vol. XXIII., pp. 343–355.

On two Plates of Stratigraphical Sections of the Taconic Ranges, by James Hall. Science, Vol. 7, pp. 393-394.

MATTHEW, GEO. F.

Illustrations of the Fauna of the St. John Group, Continued. No. III. Descriptions of New Genera and Species. Trans. Roy. Soc. Canada, Vol. 3, Sect. 4, pp. 29–84.

PANTON, J. H.

Notes on the Geology of some Islands in lake Winnipeg. Hist. and Sci. Soc. of Manitoba, Trans. No. 20, pp. 10.

PUTNAM, B. T.

Notes on the samples of Iron Ore collected in Michigan and Northern Wisconsin. Tenth Census: Report on the Mining Industries of the U. S., pp. 412–455.

SELWYN, A. R. C.

Geological and Natural History Survey of Canada. Annual Report, n. s., Vol. 1, 1885.

SMOCK, JOHN C.

A Geological Reconnaissance, in the Crystalline Rock Region Dutchess, Putnam and Westchester Counties, N. Y. 39th Annual Report of the State Mus. Nat. Hist., pp. 166–185.

VAN HISE, C. R.

Upon the Origin of the Mica-Schists and Black Mica Slates of the Penokee Gogebic Iron-bearing Series. Am. Jour. Sci., iii., Vol. 31, pp. 453–459.

WALCOTT, CHARLES D.

Classification of the Cambrian System of North America. Am. Jour. Sci., Vol. 32, pp. 138–157.

Second Contribution to the Studies on the Cambrian Faunas of North America. U. S. Geol. Survey Bulletin, No. 30.

Description of a Pteropod from the Upper Cambrian. Bull. 30, U. S. Geological Survey, pp. 223–225, 2 plates.

Cambrian Age of the Roofing Slates of Granville, Washington County, N. Y. Pamphlet extract (one page). Proc. Amer. Assoc. Adv. Sci., Buffalo meeting, August, 1886. Salem Press, December, 1886.

WHEELER, H. A.

Temperature Observations of the lake Superior Copper Mines. Am. Jour. Sci., iii., Vol. 32, pp. 125–129.

WILLIAMS, GEO. H.

The Gabbros and Associated Hornblende Rocks Occurring in the Neighborhood of Baltimore, Md. U. S. Geol. Surv. Bulletin, No. 28.

The Peridotites of the "Cortlandt Series" on the Hudson River near Peekskill, N. Y. Am. Jour. Sci., iii., Vol. 31, pp. 26–41.

WILLIS, BAILEY.

Report of a trip on the Upper Mississippi and to Vermilion Lake, Minnesota. Tenth Census: Report on Mining Industries of the U. S., pp. 457–467.

WINCHELL, N. H.

Geological and Natural History Survey of Minnesota. 14th Annual Report, for 1885, pp. 353.

The Taconic Controversy in a Nutshell. Science, Vol. 7, p. 38.

1887.

BAILEY, L. W.

On the Silurian System of Northern Maine, New Brunswick and Quebec. Trans. Roy. Soc. Canada, Vol. 4, Sect. 4, pp. 35–42.

BAILEY, L. W., and McINNES, W.

Report on Explorations in Portions of the Counties of Victoria, Northumberland and Restigouche, N. B. Geological Survey of Canada, Annual Report, Vol. 2, n. s. N, pp. 1–28.

BELL, ROBERT.

Report on an Exploration of Portions of the At-ta-wa-pish-kat and Albany Rivers. Annual Report of the Geol. Survey of Canada, Vol. 2, n. s. G, pp. 1–38.

COOK, GEO. H.

Artesian Wells. Annual Report of the Geol. Survey of N. J. for 1886, pp. [illegible]

DANA, J. D.

On Taconic Rocks and Stratigraphy, with a Geological Map of the Taconic Region. Am. Jour. Sci., iii, Vol. 33, pp. [illegible]

[illegible] the Taconic System. Am. Jour. Sci., iii, Vol. [illegible]

DAWSON, GEO. M.

Notes to accompany a Geological Map of the Northern Portion of the Dominion of Canada, East of the Rocky Mountains. Annual Report, Geol. Survey of Canada, [illegible]

[illegible] Territory. Trans. Roy. Soc. Canada, [illegible]

DAWSON, J. W.

[illegible] Canada. [illegible]

[illegible]

[illegible]

[illegible], R. W.

[illegible]

[illegible]

FARIBAULT, E. R.

Report on the Lower Cambrian Rocks of Guysborough and Halifax Counties, N. S. Annual Report of the Geol. Survey of Canada, Vol. 2, n. s. P, pp. 129–163.

FLETCHER, HUGH.

Report on Geological Surveys and Explorations in the Counties of Guysborough, Antigonish and Pictou, N. S., *l. c.*, pp. 1–128.

GRATACAP, L. P.

Eozoonal Rock of Manhattan Island. Am. Jour. Sci., xxxiii., p. 374.

HOBBS, WM. H.

On the Petrographical Characters of a Dike in the Boston Basin. Bul. Mus. Comp. Zool. No. 1, Nov., 1887.

HUNT, T. STERRY.

The Taconic Question Restated. Am. Nat., Vol. 21, Feb., March and April Nos.

The Genetic History of Crystalline Rocks. Trans. Roy. Soc. Canada, Vol. 4, Sect. 3, pp. 7–37.

IDDINGS, J. P.

The Nature and Origin of Lithophysæ, and the Lamination of Acid Lava. Am. Jour. Sci., xxxiii., p. 36.

IRVING, R. D.

Is there a Huronian Group? Am. Jour. Sci., iii., Vol. 34, pp. 204–216, 249–263, 365–374. Reviewed in Am. Geol., Vol. 1, pp. 119–120.

JULIEN, A. A.

On the Geology at Great Barrington, Mass. Trans. N. Y. Acad. Sci., Oct., 1887, pp. 21–39.

LAPWORTH, CHARLES.

Preliminary report on some Graptolites from the Lower Palæozoic Rocks on the south side of the St. Lawrence from Cape Rosier to Tartigo River, from the north shore of the Island of Orleans, one mile above Cape Rouge, and from the Cove Fields, Quebec. Trans. Roy. Soc. Canada, Vol. 4, Sect. 4, pp. 167–184.

LOW, A. P.

Preliminary Report on an Exploration of Country between lake Winnipeg and Hudson Bay. Annual Report of the Geol. Survey of Canada, Vol. 2, n. s. F, pp. 23.

LAWSON, A. C.

Geology of the Rainy Lake Region, with remarks on the classification of the crystalline rocks west of Lake Superior. Preliminary note. Am. Jour. Sci., iii., Vol. 33, pp. 473–480.

MARCOU, JULES.

On the use of the name Taconic. Proc. Bos. Soc. Nat. Hist. Vol. XXIII., pp. 344–355.

The Taconic of Georgia and the Report on the Geology of Vermont. Bos. Soc. Nat. Hist. Mem.

MATTHEW, GEO. F.

On the Cambrian Faunas of Cape Breton and Newfoundland. Trans. Roy. Soc. Canada, Vol. 4, Sec. 4, pp. 147–158.

Great American Paradoxides. Am. Jour. Sci., xxxiii. 388.

Kin of Paradoxides (Olenellus?), Kierulfi. Am. Jour. Sci., xxxiii., 390.

McCONNELL, R. G.

Report on the Geological Structure of a Portion of the Rocky Mountains. Geol. Sur. of Can., Vol. II. New series, 1887. Part D, pp. 1–40.

ROMINGER, C.

Description of Primordial Fossils from Mt. Stephens, N. W. Territory of Canada. Proc. Acad. Nat. Sci., Phil., pp. 12–19.

STEVENSON, J. J.

A Geological Reconnaissance of Bland, Giles, Wythe and Portions of Pulaski and Montgomery Counties in Virginia. Am. Phil. Soc., March, 1887.

VAN HISE, C. R.

Note on the Enlargement of Hornblendes and Augites in Fragmental and Eruptive Rocks. Am. Jour. Sci., iii., Vol. 33, pp. 385–388.

WADSWORTH, M. E.

Preliminary Description of the Peridotytes, Gabbros, Diabases and Andesytes of Minnesota. Bul. No. 2, of the Geol. and Nat. Hist. Sur. of Minnesota.

WALCOTT, CHARLES D.

Discovery of Fossils in the Lower Taconic of Emmons. Proc. Am. Assoc. Adv. Sci., Vol. 36, pp. 212–213. (Abstract.)

On the use of the term Taconic. Boston Soc. Nat. Hist. Proc., Vol. 23, pp. 343–355.

Geologic Age of the Lowest Formation of Emmons' Taconic System. Am. Jour. Sci., iii., Vol. 33, pp. 153–154.

Fauna of the "Upper Taconic" of Emmons, in Washington County, N. Y. Am. Jour. Sci. (iii.), xxxiv., p. 187.

Note on the Genus Archeocyathus of Billings. (Extract, 2 pages.) Am. Jour. Sci., Vol. 34, 1887.

Section of Lower Silurian (Ordovician) and Cambrian Strata in Central New York, as Shown by a Deep Well near Utica. (Extract.) Proc. Am. Assoc. Adv. Sci., Vol. 36, 1887, p. 212.

WILLIAMS, GEO. H.

Some Examples of Dynamic Metamorphism of the Ancient Eruptive Rocks on the South Shore of lake Superior. Am. Assoc. Adv. Sci. Proc., Vol. 36, pp. 225–226. (Abstract.)

The Norites of the "Cortlandt Series" on the Hudson River Near Peekskill, N. Y. Am. Jour. Sci., iii., Vol. 33, pp. 135–144, 191–199, 243.

Note on Some Remarkable Crystals of Pyroxene from Orange Co., N. Y. Am. Jour. Sci., xxxiv., p. 275.

WINCHELL, ALEXANDER.

Unconformability Between the Animikie and the Vermilion Series. Am. Jour. Sci., iii., Vol. 34, p. 314.

Report of Geological Observations made in Northeastern Minnesota during the Season of 1886. 15th Annual Report of the Geol. Survey of Minn. for the year 1886, Part 2, pp. 5–207.

WINCHELL, H. V.

Partial Report of Observations made by H. V. Winchell. 15th Annual Report of the Geol. Survey of Minn., Part IV., pp. 401–419.

WINCHELL, N. H.

Fifteenth Annual Report of the Geological and Natural History Survey of Minnesota for the year 1886.

Notes on Classification and Nomenclature for the American Committee of the International Geological Congress, March, 1887. Am. Nat., Aug., 1887.

1888.

ADAMS, FRANK D., and LAWSON, ANDREW C.

On some Canadian Rocks Containing Scapolite, with a few Notes on some Rocks Associated with the Apatite Deposits. Can. Record of Science, pp. 185–200.

BAYLEY, W. S.

On some Peculiarly Spotted Rocks from Pigeon Point, Minnesota. Am. Jour. Sci., iii., Vol. 35, pp. 388–393.

BONNEY, T. G.

Notes on a Part of the Huronian Series in the Neighborhood of Sudbury, Canada. Quart. Jour. Geol. Soc., Feb. 1, 1888.

BOAS, FRANZ.

The Geography and Geology of Baffins Land. Trans. Roy. Soc. Can. Sec. iv, pp. 75–78.

CARPENTER, F.

Notes on the Geology of the Black Hills. Preliminary Report of the Dakota School of Mines, pp. 11–52. Reviewed in Am. Geologist, Vol. III., p. 202.

CLAYPOLE, EDWARD W.

On some Investigations Regarding the Condition of the Interior of the Earth. Am. Geol., Vol. II., p. 28.

COLLINS, J. F.

The Sudbury Copper Deposits. Quart. Jour. Geol. Soc., Vol. XLIV., p. 834.

CROSBY, W. O.

The Geology of the Black Hills, Dakota. Boston Soc. Nat. Hist. Proc., Vol. 23, p. 488. Am. Jour. Sci., iii., Vol. 36, p. 153.

Geology of the Outer Islands of Boston Harbor. Proc. Boston Soc. Nat. History, Vol. 23, pp. 450–457.

DANA, J. D.

A Brief History of Taconic Ideas. Am. Jour. Sci., iii., Vol. 36, pp. 410–427.

DAWSON, J. W.

On the Eozoic and Palæozoic Rocks of the Atlantic Coast of Canada in Comparison with those of Western Europe and the Interior of America. Quart. Jour. Geol. Soc., London, Vol. 44, p. 797. Canadian Rec. Sci., Vol. 3, pp. 182–183. (Abstract.)

DWIGHT, W. B.

Discovery of Additional Fossiliferous Potsdam and Pre-Potsdam Strata of the Olenellus Group near Poughkeepsie, N. Y. Am. Jour. Sci., iii., xxxiv., p. 27.

Fossiliferous Strata of the Paradoxides Zone at Stissing, N. Y. Am. Jour. Sci., iii., xxxviii., 139.

FRAZER, PERSIFOR.

Report of the Sub-committee on the Archæan. Am. Committee Reports, Int. Cong. Geol., pp. 1–52. Am. Geol., Vol. 2, pp. 143–192.

HAWORTH, ERASMUS.

A Contribution to the Archæan Geology of Missouri. Am. Geol., Vol. 1, pp. 280–297; 363–382. (Preliminary notice in the Johns Hopkins University Circulars, Vol. 7, No. 65, p. 70.)

HERRICK, C. L., CLARKE, E. S., and DEMING, J. L.

Some American Norytes and Gabbros. Geological Notes from the Laboratory of Denison University. Am. Geol., Vol. 1, pp. 339–346.

HITCHCOCK, C. H.

Date of the Publication of the Report upon the Geology of Vermont. Proc. Boston Soc. Nat. Hist., Vol. XXIV., pp. 33-37.

HUNT, T. STERRY.

Les Schistes Cristallins. From the Etudes sur les Schistes Cristallins. International Geol. Congress, London, 1888.

IRVING, R. D., CHAMBERLIN, T. C., and VAN HISE, C. R.

The Crystalline Schists of the lake Superior District. Intern. Geol. Congress, London, pp. 92-106.

On the Classification of the Early Cambrian and pre-Cambrian Formations. 7th Annual Report U. S. Geol. Survey, pp. 368–454.

IVES, JAMES T. B.

Iron and Other Ores of Ontario. Canadian Inst. Proc., Vol. 5, pp. 185–192.

JUDD, J. W.

Growth of Crystals in Igneous Rocks after Consolidation. Quart. Jour. Geol. Soc., Vol. XLV., p. 175.

KEMP, J. F.

Diorite Dike of Forest of Dean, Orange County, N. Y. Am. Jour. Sci., Vol. 35, p. 331.

On the Rosetown Extension of the Cortlandt Series. Am. Jour. Sci., iii., Vol. 36, pp. 247–253.

The Dikes of the Hudson River Highlands. Am. Nat., Aug., pp. 691–98.

LAWSON, A. C.

The Diabase Dykes of Rainy Lake. Canadian Inst. Proc., Vol. 5, pp. 173-185. Am. Geol., Vol. 1, pp. 199-211.

The Archæan Geology of the Region Northwest of lake Superior. Études sur les schistes cristallins: reviewed in Am. Geologist, Vol. IV., p. 59. Intern. Geol. Congress, London, pp. 66-88.

MARCOU, JULES.

American Geological Classification and Nomenclature. Cambridge, pp. 75.

On Some Dates of the "Report on the Geology of Vermont." Proc. Bos. Soc. Nat. Hist., Vol. XXIII., pp. 83-89.

Palæontologic and Stratigraphic "Principles" of the Adversaries of the Taconic. Am. Geol., Vol. II., pp. 9-43, 67-88.

Geology of the Vicinity of Quebec City. Am. Geol., Vol. II, p. 355.

MATTHEW, G. F.

On a Basal Series of Cambrian Rocks in Acadia. Canadian Rec. Sci., Vol. III., pp. 21-29.

On the Classification of the Cambrian Rocks in Acadia. *l. c.*, pp. 71-81.

On Psammichnites and the Early Tribolites of the Cambrian Rocks in Eastern Canada. Am. Geol., Vol. 2, pp. 1-9.

Illustration of the fauna of St. John group. No. iv. Part I, descriptions of a new species of Paradoxides (*Paradoxides Regina*). Part II., the smaller trilobites with eyes (*Ptychoparia Ellipsocephalidæ*). Trans. Roy. Soc. Can., Sec. iv., pp. 115-166.

McGEE, W. J.

Three Formations of the Middle Atlantic Slope. Am. Jour. Sci., iii., Vol. XXXV., pp. 120-143, 328-343, 367-388, 448-466.

McKELLAR, PETER.

The correlation of the Animike and Huronian rocks of lake Superior. Trans. Roy. Soc. Can., Sec. iv., pp, 63-73.

MERRILL, G. P.

Note on the Secondary Enlargement of Augites in a Peridotite from Little Deer Isle, Maine. Am. Jour. Sci., xxxv., p. 488.

MILLER, S. A.

The Taconic System as Established by Emmons, and the Laws of Nomenclature Applicable to the Subject. Am. Geol., Vol. 1, pp. 235-245.

PENROSE, R. A. F.

Nature and Origin of Deposits of Phosphates of Lime. Bul. U. S. Geol. Survey, No. 46.

RICHARDS, GARY F.

Lithological Notes on Contact Phenomena in South Carolina. Pl. XV. Bul. Denison University, Vol. IV., pp. 5-10.

SELWYN, A. R. C.

The Taconic at Quebec. Am. Geol., Vol. II., p. 134.

The Huronian of Canada. Am. Geol., Vol. II., pp. 61-62.

VOGDES, A. W.

Some Forgotten Taconic Literature. Am. Geol., Vol. II., p. 352.

WALCOTT, CHARLES D.

- The Taconic System of Emmons, and the Use of the Name Taconic in Geological Nomenclature. Am. Jour. Sci., iii., Vol. 35, pp. 229–242, 307–327, 394–401.

Cambrian Fossils from Mount Stephens, Northwest Territory of Canada. Am. Jour. Sci., Vol. XXXVI., pp. 161–167.

The Stratigraphical Succession of the Cambrian Faunas in North America. Nature, Vol. 38, No. 988, p. 551.

WILLIAMS, G. H.

The Gabbros and Diorites of the "Cortlandt Series" on the Hudson River, near Peekskill, N. Y. Am. Jour. Sci., iii., Vol. 35, pp. 438–448.

The Contact Metamorphism Produced in the Adjoining Mica-Schists and Limestones by the Massive Rocks of the "Cortlandt Series," near Peekskill, N. Y. Am. Jour. Sci., iii., Vol. 36, pp. 254–269. Johns Hopkins Univ. Circulars, Vol. VII., p. 63.

Progress of the Work on the Archæan Geology of Maryland. Johns Hopkins University Circulars, Vol. VII., No. 65, p. 61.

Contributions to the Mineralogy of Maryland. Johns Hopkins Univ. Circulars, No. 75.

WINCHELL, ALEXANDER.

Report of a Geological Survey in Minnesota during the Season of 1887. Sixteenth Annual Report of the Geol. Survey of Minn., pp. 133–391.

The Unconformities of the Animike in Minnesota. Am. Geol., Vol. 1, pp. 14–24.

The Taconic Question. Am. Geol., Vol. 1, pp. 347–363.

Some Effects of Pressure of a Continental Glacier. Am. Geol., Vol. I., p. 139.

WINCHELL, H. V.

Report of observations made during the summer of 1887. Sixteenth Annual Report of the Geol. Survey of Minn., pp. 395–478.

WINCHELL, N. H., and UPHAM, WARREN.

Geology of Minnesota. Volume II. of the final reports.

WINCHELL, N. H.

Sixteenth Annual Report of the Geol. Survey of Minn. for the year 1887.

The Animike Black Slates and Quartzytes, and the Ogishke Conglomerate of Minnesota, the equivalent of the "Original Huronian." Am. Geol. Vol. 1, pp. 11–14.

Some objections to the term Taconic considered. *l. c.*, pp. 162–172.

A great Primordial Quartzyte. *l. c.*, pp. 173–178.

Report of the Sub-committee of the American International Committee, on the Lower Palæozoic. (Int. Cong. Geol.) Am. Geol., Vol. 2, pp. 193–224.

1889.

BAYLEY, W. S.

A Quartz-Keratophyre from Pigeon Point and Irving's Augite Syenites. Am. Jour. Sci., iii., Vol. 38, pp. 54–63.

BELL, ROBERT.

Presidential Address: The Huronian System of Canada. Trans. Roy. Soc. Can., Sec. IV., Vol. VI., pp. 3–14.

BRANNER, J. C.

The Age of the Crystalline Rocks of Arkansas. A. A. A. S., Cleveland Meeting, p. 188. (Abstract.)

The Peridotytes of Arkansas (in connection with R. N. Brackett). A. A. A. S., Cleveland Meeting, p. 188. (Abstract.)

BROADHEAD, G. C.

The Geological History of The Ozark Uplift. Am. Geol. Vol. III., p. 6.

BROWNE, D. H.

The Distribution of Phosphorus in the Luddington Mine, Iron Mountain, Michigan, with plates VIII–XIII. Am. Jour. Sci., Vol. XXXVII., pp. 299–310. Vol. XXXVIII. pp. 29–42.

HALL, C. W.

The Distribution of the Granites of the Northwestern States, and their general lithologic characters. A. A. A. S., Cleveland Meeting, p. 189. (Abstract.)

HITCHCOCK, C. H,

Conglomerates in New England Gneisses. Am. Geol., Vol. III., p. 253.

HOBBS, WM. H.

On the Rocks Occurring in the Neighborhood of Ilchester, Howard county, Maryland; being a detailed study of the area comprised in sheet No. 16 of the Johns Hopkins University map. (A preliminary notice.) Johns Hopkins University Circulars. Vol. VII., No. 65, p. 69.

HOWLEY, J. P.

The Taconic of Eastern Newfoundland. Am. Geol., Vol. IV., p. 121.

IDDINGS, JOSEPH PAXSON.

On the Crystallization of Igneous Rocks. Bull. Phil. Soc. Wash., Vol. II., pp. 71–113.

KEMP, J. F., and V. F. MARSTERS.

On certain Camptonite Dikes near Whitehall, N. Y. Am. Geologist, Vol. IV., p. 97.

LAWSON, A. C.

Foliation and Sedimentation. Am. Geol., Vol. 3, pp. 169–178.

Report on the Geology of the Rainy Lake Region. Geol. and Nat. Hist. Sur. Can., Part F. Annual report, Vol. III., 1887.

LE CONTE, JOSEPH.

The General Interior Condition of the Earth. Am. Geol., Vol. IV., p. 38.

MARCOU, JULES.

Canadian Geological Classification for the Province of Quebec. Boston Soc. Nat. Hist. Proc., Vol. 24, pp. 54-83.

Barrande and the Taconic System. Am. Geol., Vol., 3, pp. 118-137.

MATTHEW, G. F.

On the Classification of the Cambrian Rocks in Acadia. Can. Rec. Sci., p. 303.

How is the Cambrian Divided? Am. Geol., Vol. IV., p. 139.

Cambrian Organisms in Acadia. Can. Rec. of Sci., July.

McCONNELL, R. G.

Note on the Geology of Mt. Stephen, British Columbia. Am. Geol., Vol. III., p. 22.

MEADS, A. D.

The Stillwater, Minn., Deep Well. Am. Geol., Vol. III., p. 342.

MERRILL, GEO. P.

On the Ophiolite of Thurman, Warren county, N. Y., with remarks on the Eozoon Canadense. Am. Jour. Sci., Vol. XXXVII., March, pp. 189–190.

READE, T. MELLARD.

Physical Theories of the Earth in relation to mountain formation. Am. Geol., Vol. III., p. 106.

SELWYN, A. R. C.

Two Systems Confounded in the Huronian. Am. Geol., Vol. III., pp. 339–340.

SMOCK, JOHN C.

First Report on the Iron Mines and Iron Ore Districts of New York. Bul. N. Y. State Mus., No. 7. Albany.

VAN HISE, C. R.

The Iron Ores of the Penokee-Gogebic Series of Michigan and Wisconsin. Am. Jour. Sci., iii., Vol. 37, pp. 32–48.

WALCOTT, CHAS. D.

Stratigraphic Position of the Olenellus Fauna in North America and Europe. Am. Jour. Sci., Vol. XXXVII., pp. 374–392; Vol. XXXVIII., pp. 29–42.

Description of New Genera and Species of Fossils from the Middle Cambrian. Proc. U. S. National Museum, 1888, pp. 441–446, one cut. Advance sheets issued June 11, 1889.

WILLIAMS, G. H.

On the Possibility of Hemihedrism in the Monoclinic Crystal System, with especial reference to the Hemihedrism of Pyroxene.

WINCHELL, H. V.

The Diabasic Schists Containing the Jaspilyte Beds of Northeastern Minnesota. Am. Geol., Vol. 3, pp. 18-22.

WINCHELL, ALEXANDER.

Conglomerates Enclosed in Gneissic Terranes. Am. Geologist, Vol. III., pp. 153-165, 256-262.

Two Systems Confounded in the Huronian. Am. Geologist, Vol. III., pp. 212-214.

Systematic Results of a Field Study of the Archæan Rocks of the Northwest. A. A. A. S., Cleveland, p. 205. (Abstract.)

WINCHELL, N. H.

Some Thoughts on Eruptive Rocks, with Special Reference to those of Minnesota. A. A. A. S., Cleveland, pp. 212-221.

WINCHELL, N. H. and H. V.

On a Possible Chemical Origin of the Iron Ores of the Keewatin in Northeastern Minnesota. A. A. A. S., Toronto meeting, August; Am. Geol., November.

GENERAL INDEX.

ACID eruptives during the Potsdam, 55.
Adams, Prof. C. B., 60.
Age of the crystalline schists, 31; of the Taconic, 46; of the Potsdam, 51; of the St. Croix sandstone, 56.
Akeley lake, 52, 193.
Alice lake, 78, 190, 191.
Analysis of green rock, 126; of iron ore, 80, 81, 90, 97.
Animike, 10, 15; age of the, 46; as "Muscovado," 130, 131; at Disappointment lake, 116, 117; at Frazer and Thomas lakes, 193; at Gunflint lake, 104, 105, 106, 107, 108, 155, 159; at Iron lake, 84, 85; at lake Isabelle, 99, 100; at Meed's lake, 172, 173; at Ogishke-Muncie, 109, 110, 111; conglomeritic, 85; contained in gabbro, 96; difference from the Kewatin, 134, embracing Ogishke conglomerate, 20; equivalent to the Huronian, 23, 24, 26, 27; in Birch lake region, 93, 94, 95, 96, 97, 163; in Giant's range region, 86, 87, 88, 89, 90, 91, 92, 134; in relation to gabbro, 52, 54, 96; in relation to the Ogishke conglomerate, 17, 19, 20; in relation to the Pewabic, 50; jasper in, 85; magnetite, 79, 80, 81; of Thunder bay, 18; overlying the Kewatin, 38, 43, 44, 45, 72, 107, 108, 109; overlying the syenite, 94; quartzyte, 19, 133; stratigraphy of, 68, 70, 71; transition to syenite, 81, 133.
Annual reports, progress in, 11; first, 11; second, 13; sixth, 13; seventh, 13; eighth, 14; ninth, 15; tenth, 15; eleventh, 18; thirteenth, 19; fifteenth, 20, 21, 40; sixteenth, 22, 23, 24.
Appendix. List of geological publications, 227.
Archæan, 10, 12, 25, 68, 73.
Archæological collection, 4.
Aurora mine, 31.
Azoic, 9. 10, 11, 12, 25, 62.

BALD Eagle lake, 99, 164.
Baptism river, 18.
Baraboo quartzyte, 50, 51.
Baraboo, Wisc., 13; unconformity at. 12.
Barometrical elevations, 144, 200.
Barron county quartzyte, 50.
Basswood lake, 13, 19, 29, 30.
Beargrease, John, 82.
Beaver Bay, 17, 18, 53, 54.
Beaver creek, 90.
Bell Robert, 7, 14, 15.
Bellissima lake, 100, 167.
Big Stone lake, 13, 30.
Birch lake, 22, 30, 31, 77, 78, 79, 81, 91, 92, 93, 95, 96, 106, 129, 193; elevation of, 144.
Birch lake region, 92-98, 162.
Blackfly bay, 152, 159.
Braintree quartzyte, 50, 51.
Brooks Maj. T. B., 10, 31, 32, 48, 69, 71, 72.
Brulé lake, 78, 150, 168, 176, 177, 178, 179.
Brulé mt., 16.
Brulé river, 13; elevation of, 144.

CALCIFEROUS, 51, 59, 60, 61, 62, 63, 68.
Cambrian, 10, 25.
Caribou lake, 171, 172, 173.
Chalcedonic quartz, 40, 87.
Chamberlin, Pres. T. C., 9, 11.
Chandler mine, 79, 98.
Charley lake, 184.
Cheadle, Mr. H. W., 116.
Chester, Prof. A. H., 19, 87.
Chub lake, 52, 108, 109, 160, 193.
Cleaves, Lorenzo, 96.
Comparison of results, 68.
Conglomerate, at Disappointment lake, 117, 118; at Ogishke-Muncie, 16, 119.
Conglomerate and diabase, 117.
Conglomeritic mica schist, 116, 117, 118, 120; syenite, 159; structure observed, 86, 145.
Conniff, Mr. J. F., 151.
Contacts observed, 144.
Conversion of hornblende schists into mica schists, 82.
Copeland, Hugh, 123.
Coutchiching, 19, 32, 37, 68, 73.
Crooked lake, 102.
Crystalline rocks of Minnesota, 6; early views on, 7.
Crystalline schists, 11, 28, 29, 65; age of, 31; origin of, 66.
Cupriferous, 14, 15, 17, 18, 24, 101, 108, 135, 167, 168.

DANA, Prof. J. D. 9, 12, 25.
Dawson, Dr. G. M., 61, 182.
Devil's Track river, 144.
Diarmid. Mr. Wm., 164.
Dikelocephalus, 62.
Dikelocephalus fauna, 51.
Dikelocephalus horizon, 68.
Dioritic group of Rominger, 44, 45.
Disappointment lake, 115, 119, 120, 121, 124; "Muscovado" at, 130; elevation of, 144.
Distribution of the Laurentian in Minnesota, 29.
Disturbance during the Potsdam, 52.
Draper lake, 169, 184.
Drift, 86, 92, 95, 102.
Duck lake, 171.
Duluth and Iron Range railroad, 79.
Duncan's lake, 144.
Dunka river, 85, 92, 162.

EAMES, H. H., 7, 8.
Early views on crystalline rock of Minnesota, 7.
Effect of hydrothermal fusion, 35.
Eighth annual report, 14.
Eleventh annual report, 18, 87.
Elevations, 144, 200.
Ely, Minn., 77, 79, 98, 112, 118, 121, 149.
Emmons, Dr. Ebenezer, 9, 18, 26, 47, 48, 49, 50, 51, 55, 58, 60, 61, 62, 63.
Ensign lake, 115, 144.
Eruptive Laurentian, 65, 73.
Eruptive syenite, 30.

FALL lake, 42.
Field work in 1888, 1.
Fifteenth annual report, 20, 21, 40.
Final reports, 2.
First annual report, 11.
Flying Cloud lake, 168, 184, 185.
Fond du Lac, 16.
Fossils, primordial, 19, 46, 51; species of, 19, 62, 63.
Foster and Whitney, 8, 9, 11, 12, 25, 61.
Found lake, 169, 179, 180, 182.
Frazer lake, 187, 189, 190, 193.

"GABBRO," 17; date of outflow, 82.
Gabemichigama lake, 47, 110.
Gabiskamak lake, 190.
Gaokakag lake, 101.
Gaskanas lake, 163, 173, 174.
Georgia group, 18, 49.
Georgia, lake, 169, 178, 179
Giant's range, 21, 22, 77, 81, 83, 84, 87, 92, 93, 106, 129; eruptive syenite of, 30, 88, 89, 128, 131; transition of Animike to syenite, 133.
Glaciation, 86, 88, 89, 92, 93, 94, 95, 98, 99, 100, 102, 113, 115, 117, 118.
Gogebic iron region, 22.
Gradations between Laurentian and Huronian, 14; Vermilion and Kewatin, 87; mica schist, and diabase, 118; Animike and syenite, 133.
Grand Portage, 13
Grand Portage bay, generalized section at, 15.
Grand Portage island, 15.
Grand Rapids, 128.
Grant, Uly. S., 1, 4, 31, 77, 78, 102; reports of, 147.
"Granular quartz," 23, 25, 46, 51, 55, 60.
Granular quartz, the, 48 49, 50, 51, 58, 63.
Great Palisades, 18, 71.
Great quartzyte, 51.
Greenstone, 38, 41, 107, 108, 109, 110, 185, 186.
"Greenstone belt," 24.
"Gunflint beds," 16, 19.
Gunflint lake, 78, 149, 150, 158, 168, 169, 174, 185; Animike at, 134, 172; elevation of, 144; gneiss at, 30; Kewatin at, 19, 42, 72, 133; ore at, 80; region of, 104–111, 129; schists at, 19, 31, 159; section at, 15; slates at, 17, 152.
Gunflint lake and vicinity, 151-161.
Gull lake, 191.

HALL, Prof. C. W., 14.
Hall, Prof. James, 7, 8, 12, 19, 57, 61, 62, 63.
Harriet lake, 101, 102, 167.
Hatch, Dr. P. L., 2.
Herrick, Prof. C. L., 2.
Hinsdale, 88, 89, 106, 128, 129.
Hitchcock, Prof. C. H.; 10, 55, 56, 73.
Hitchcock, Dr. E., 49, 50, 51, 55, 59, 60.
Heinze Brothers, 173, 183.
Hornblende schists converted into mica schists, 32.
Houghton, Dr. Douglass, 7, 8, 48.
Howe, Mr. Chas. F., 128.
Hunt, T. Sterry, 11, 15.
Huron, lake, 22, 61.
Huronian, 8, 9, 10, 11, 12, 14, 15, 17, 18, 19, 22, 23, 25, 26, 27, 43, 46, 47, 48, 49, 50, 52, 53, 55, 57, 61, 62, 64, 68, 69, 70, 71, 72, 73, 80, 133.
Huronian conglomerates and greenstone, 19.
Huronian quartzyte, 128, 134, 135.
Hydrothermal fusion, effects of, 35; planes of 66.
Hypersthene rock, 63, 64.

IDA BELLE lake, 168, 169, 180, 182, 183, 192.
Ima lake, 189.
Iron group, of Rominger, 48.
Iron lake, 83, 84, 85, 169, 170.
Iron ores, analysis of, 80, 81, 91, 97; Birch lake, 93; Chub lake, 160; Disappointment lake, 117; Giant's range, 82, 83, 86, 87, 89, 91, 92; Gunflint lake, 106, 107, 108, 110; Kawishiwi river, 96, 163; Mayhew lake, 169; Meed's lake, 172; Flying Cloud lake, 185; Frazer lake, 187; Thomas lake, 189; Township 63-9, 123; varieties of, 79-81; Vermilion, 39; the Vermilion distinct from the Mesabi, 19.
Iron ores of Marquette, 43.
Iron ores of the Taconic, 48.
Iron regions of Minnesota, report on, 77.
Irving, Prof. R. D., 8, 11, 12, 17, 26, 27, 32, 48, 54, 57, 62, 69, 70.

Isabelle lake, 99, 100, 166.
Ishpeming, 44, 45.
Isle Royale, 16, 20.
Itasca lake, 29.

JASPILYTE, origin of, 40, 68, 182; in the Kewatin, 45; Otter Track lake, 111, 112; township 63-9, 122; inclosed in basic rock, 123.

KAKEGO lake, 185.
Kaminisabikokak lake, 100.
Kapokegamak lake, 102.
Kawasachong rock, 24, 42.
Kawishiwin, 42, 45, 46, 68, 70.
Kawishiwi river, 30, 42, 77, 96, 97, 120, 128, 131, 144, 150, 168, 190, 191.
Kawishiwi lake, 150.
Kazushkonabigka-gamak, 99.
Kearny, Mr., 128.
Keeseville, 58, 61, 62, 63; sandstone, 63.
Kekekebic lake, 30, 31, 43.
Kewatin, 14, 19, 22, 24, 31, 32, 33, 46, 47, 48, 52, 129, 130, 131, 132, 133, 134, 150; age of, 37, 38; Bald Eagle lake, 99; Birch lake region, 93, 94; difference from the Animike, 134; Giant's range, 87, 88, 89, 91, 92; Gunflint lake, 104, 105, 106, 152, 155, 157, 159; "greenstone" stage, 41, jaspilyte of, 40, 45; nature of the, 37, 38, 39, 67; Ogishke Muncie, 107, 109; ores of, 39, 80, 81; Otter Track lake, 112, 113, 114; parallels of, 42, 43, 44; Prairie River falls, 128; schists, 14, 37; stratigraphic position of, 68, 70, 72, 73.
Kewatin and the Vermilion, 66.
Kewatin bay, 157.
"Kewatin stuff," 32.
Kewenian, 14.
Keweenawan, 14, 15, 18, 24, 35, 53, 54, 55, 68, 69, 70, 73.
Kiskadinna lake, 183, 184.
Kloos, Dr. J. H., 8.
Knife lake, 99, 104, 112, 115, 127, 144.

LAKE of the woods, 31, 72, 130, 132.
Lake Superior, 13, 15, 24, 54, 61, 71, 77, 99, 100, 103, 149, 150.
Laurentian, 8, 10, 15, 20, 21, 22, 23, 25, 27, 32, 33, 34, 35, 36, 38, 48, 50, 52, 54, 55, 56, 57, 59, 60, 62, 66, 68, 69, 71, 73; age, the, 28; eruptive and sedimentary, 65; in Minnesota, 29, 30.
Lawson, Dr. A. C., 14, 17, 19, 22, 31, 32, 33, 34, 36, 37, 72, 73, 98, 130, 132.
Lesquereux, Dr. Leo, 2.
Lingula antiqua, 62, 63; acuminata, 63; calumet, 19, prima, 62, 63.
Little Falls, Minn., 13.
Logan, Sir Wm., 11, 22, 25, 47, 49, 61.
Long lake, 79, 97, 112.
Loon lake, 105, 106, 144, 169, 172.
Lost lake, 169, 176, 177.
Lower Cambrian, 22, 25, 26, 27, 46.
Lower Magnesian, 62.

MALLMANN, John, 89, 90.
Marcou Jules, 49, 51.
Marquette, formations of, 10, 19, 22, 23, 42, 43, 44, 48.
Marvine, A. R., 11.
Maskigo-sibi, 100.
Mather, W. W., 48, 50, 61.
Mayhew lake, 16, 105, 169, 170.
McConnell, R. G., 46.
Medina sandstone, 60.
Meeds, Mr. A. D., 77, 149, 172, 181.
Meeds' lake, 169, 172.
Menominee, iron district of, 48.
Mesabi range, 14, 16, 19, 20, 23, 27, 47, 48.
Method of labeling specimens, 4.
Millar, Mr. John M., 108, 160.
Minnesota Valley, 13, 14.
Mishiwishiwi lake, 99, 164, 165, 192.
Missasaugui quartzyte, 47.
Mitchell, Peter, 82, 86.
Monkton, 60.
Morton, Minn., 29.
Motley, Minn., 13.
Mountain lake, 174.
Murchison, 9, 11.
Murray, 8, f. note, 22, 25.
Murray bay, 61.
Muscovado rock, 45, 68, 93, 100, 116, 117, 120, 128, 130, 131, 168, 170, 181, 185, 187, 188, 189.
Museum, condition of, 8; additions to, 218.

NARROW lake, 169, 183.
Nature of the Kewatin rocks, 37.
Nature of transition from Laurentian to Vermilion, 33.
Negaunee, 44, 48.
New Ulm, 8, 13.
New Ulm quartzyte, 50.
Nine Mile lake, 102.
North Brulé lake, 173.
North lake, 144.
Northern Pacific Junction, 13.
Norwood, J. G., 7, 8, 12, 54.

OBOLELLA, 62.
Ogishke-Muncie lake, 17, 43, 47, 106, 110, 161, 168.
Ogishke conglomerate, 16, 17, 19, 20, 23, 24, 47, 110, 111, 119.
Olenellus horizon, 48, 50, 68.
Origin of jaspilyte, 40, 68.
Otter Track lake, 111, 112, 113, 114, 150, 151.
Owen, Dr. D. D., 12, 62.

PALISADE rock, 16, 18, 21.
Paradoxides barberi, 19.
Paradoxides horizon, 46, 50, 51, 68.
Parallels of the Kewatin, 42.
Partridge river, 90, 91.
Partridge lake, 190.
Pe-na sagiagan lake, 190.
Penokee Gogebic range, 24, 47, 48.

Pewabic quartzyte, 23, 50, 51, 52, 64, 111, 160, 185, 186, 189.
Pigeon Point, 13, 16, 20, 46.
Pine, 113, 173, 176, 189.
Pine island, 191.
Pine lake, 102, 167.
Pine mountain, 144.
Pioneer mine, 79.
Pipestone, 8; quartzyte at, 64.
Planes of hydrothermal fusion, 66.
Plats, erroneous, 109, 168, 176, 178, 184.
Plummer argillytes, 50.
Pokegama falls, 128.
Poplar lake, 53, 58, 70, 171.
Pork bay, 103.
Portage lake, 170, 171.
Post-gabbro eruptions of the Potsdam, 54.
Potsdam, 12, 13, 14, 15, 18, 25, 49, 51, 52, 55, 53, 57, 58, 59, 60, 61, 62, 63, 68, 70; acid eruptions during, 55; disturbance during, 52; post-gabbro eruptions of, 54; unconformable on Taconic, 51.
Potsdam and Keesville sandstone, 58, 61.
"Potsdam group," 61, 62.
Potsdam quartzyte, 23, 49, 50.
Potsdam sandstone, 8, 12, 14, 15, 18, 50, 51, 53, 58, 70.
Prairie River falls, 128.
Primary rocks, 9.
Primordial fossils in Minnesota, 19, 64.
Problems unsolved, 10, 64–68.
"Prospect mountain" quartzyte, 51.
Pumpelly, Prof. R., 10.
Pyrocrystalline rocks, 9.
Pyroplastic rocks, 9.

QUARTZYTE, Baraboo, 12, 50, 51; Missasaugui, 47; Pewabic, 23, 50, 52, 64; Sioux, 50, 51; Thessalon, 50, 51, 64, 70; Wauswaugoning, 19, 50, 51, 64.
"Quebec group," 53.

RAINY lake, 32, 35.
Red quartzyte in Minnesota, 13.
"Red rocks," 21, 23, 173, 192.
Red sandrock, 51.
Redwood Falls, 8.
Report of H. V. Winchell, 75.
Report of N. H. Winchell, 1.
Report of U. S. Grant, 147.
Results of investigation, 28.
Results compared, 68.
Rock samples, method of labeling, 4; collected by H. V. Winchell, 135–144, by U. S. Grant 198–200, 201–215.
Rominger, Dr. C., 11, 24, 31, 32, 42, 43, 44, 48, 50, 51, 71, 72.
Rose lake, 144.
Round lake, 119, 144, 169, 183, 184.

SAGANAGA lake, granite, 29, 159.
Schoolcraft, 7, 8.
Second annual report, 13.
Section at Grand Portage bay, 15.
Serpentine group of Rominger, 24, 42.
Sericitic schists, 68.
Seventh annual report, 10.
Sham lake, 169, 174, 175, 176.
Shoo-fly lake, 186, 187.
Sidener, C. F., 80, 81, 90, 97, 126.
Silurian, 57, 59, 60.
Sioux quartzyte, 50, 51.
Sixteenth annual report, 22, 23, 24.
"Slaty quartzyte," 18.
Snowbank lake, 78, 115, 119, 120, 129, 144.
South lake, 144.
Specimens, method of labeling, 4; collected by H. V. Winchell, 135; U. S. Grant, 198, 201.
St. Croix river, 62, 63.
St. Croix sandstone, 12, 56, 60, 61, 62, 63; age of, 56, 57, 68.
St. Louis river, 13.
Steps of progress, 25.
Stillwater, 62.
Straight lake, 169, 171.
Stray lake, 169, 173.
Stuntz island conglomerate, 24.
Sucker, Charley and Nick, 149.
Summary statement, 1.
Surveyor's lake, 169, 179.
Swamp Lake river, 100.
Sweet, E. T., 11.
Syenite, eruptive, 30, 193; Giant's range, 128, 131; overlying gabbro, 175, 181, 193.

TACHE, J. C., 8, f, note.
Taconic, 9, 10, 15, 18, 19, 25, 26, 27, 45, 46, 48, 50, 51, 52, 54, 55, 56, 58, 60, 61, 62, 68; age of the, 46, 47; iron ores of the, 48.
Taylor's Falls, 63.
Teal lake quartzyte, 51.
Tenth annual report, 15.
Thirteenth annual report, 19.
Thessalon quartzyte, 50, 51, 53, 64, 70.
Thomas, B. W., 2.
Thomas lake, 189, 190, 193.
Thomson slates, 54.
Titaniferous ore, 80, 81.
Tonga or Dunka river, 92.
Tower, 38, 40, 41, 77, 89, 122, 124.
Town Line lake, 17.
Transitions observed, 145; from the Laurentian to the Vermilion, 33; Kewatin to Vermilion, 37; mica schists to diabase, 118; Animike to syenite, 133.
Tucker lake, 105, 135.

ULRICH, E. O., 2.
Unconformity of Potsdam upon the Taconic, 51.
Unsolved problems, 10, 64–68.
Upham, Mr. Warren, 14.

VANUXEM, L., 61.
Varieties of iron ores, 79-81.
Vermilion group, 19, 20, 31, 33, 34, 35, 36, 37, 38, 48, 66, 68, 73, 130, 150, 159; age of the, 33, 34, 35.
Vermilion iron ores, 39.
Vermilion lake, 18, 19, 20, 21, 24, 40, 80, 87, 191.
Vira lake, 115, 144.

WADSWORTH, Dr. M. E., 6, 11, 45.
Walcott, C. D., 46, 49, 50.
Wauswaugoning quartzyte, 19, 50, 51, 64.
West Haven, Vt., 59, 60.
Willard, W. D., 77, 85, 90.
Winchell, Dr. A. 4, 8, 10, 12, 27, 130, 132, 133, 159.
Winchell, H. V., 1, 4, 31, 35, 41, 150, 151, 162, 164, 166, 168; report of, 75.
Winchell, Prof. N. H., 4, 132, 149, 171, 176; report of, 5.
Winchell lake, 174, 176, 178, 193.
Wilder lake, 190, 191.
Woodward, A., 2.
Wright, Prof. C. E., 11, 71.

ZENITH mine, 79.

PUBLICATIONS OF THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

I. ANNUAL REPORTS.

The First Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1872. 112 pp., 8vo.; with a colored map of the state. By *N. H. Winchell*. Published in the Regents' Report for 1872. Second edition identical.

The Second Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1873. 145 pp., 8vo.; with illustrations. By *N. H. Winchell* and *S. F. Peckham*. Published in the Regents' Report for 1873. Out of print.

The Third Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1874. 42 pp.; 8vo.; with two county maps. By *N. H. Winchell*. Published in the Regents' Report for 1874. Out of print.

The Fourth Annual Report of the Geological and Natural History Survey of Minnesota, for the year 1875. 162 pp.; 8vo.; with four county maps and a number of other illustrations. By *N. H. Winchell*, assisted by *M. W. Harrington*. Also in the Regents. Report for 1875. Out of print.

The Fifth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1876. 248 pp.; 8vo.; four colored maps and several other illustrations. By *N. H. Winchell;* with reports on Chemistry, by *S. F. Peckham;* Ornithology by *P. L. Hatch;* Entomology, by *Allen Whitman;* and on Fungi, by *A. E. Johnson*. Also in the Regents' Report for 1876. Out of print.

The Sixth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1877. 226 pp.; 8vo.; three geological maps and several other illustrations. By *N. H. Winchell;* with reports on Chemical Analyses, by *S. F. Peckham;* on Ornithology, by *P. L. Hatch;* on Entomology, by *Allen Whitman;* and on Geology of Rice county, by *L. B. Sperry*. Also in the Regents' Report for 1877. Out of print.

The Seventh Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1878. 123 pp.; 8vo., with twenty-one plates. By *N. H. Winchell;* with a Field Report, by *C. W. Hall;* Chemical Analyses, by *S. F. Peckham;* Ornithology, by *P. L. Hatch;* a list of the Plants of the north shore of Lake Superior, by *B. Juni;* and an Appendix, by *C. L. Herrick* on the Microscopic Entomostraca of Minnesota, twenty-one plates. Also in the Regents' Report for 1878. Out of print.

The Eighth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1879. 183pp., 8vo., one plate (Castoroides). By *N. H. Winchell.* Containing a statement of the methods of Microscopic Lithology, a discussion of the Cupriferous Series in Minnesota, and descriptions of new species of brachiopoda from the Trenton and Hudson River formations; with reports on the Geology of Central and Western Minnesota, by *Warren Upham;* on the Lake Superior region, by *C. W. Hall;* lists of Birds and of Plants from Lake Superior, by *Thomas S. Roberts;* Chemical Analyses, by *S. F. Peckham;* Report by *P. L. Hatch;* and four Appendixes. Also in the Regents' Report for 1879 and 1880. Out of print.

The Ninth Annual Report on the Geological and Natural History Survey of Minnesota, for the Year 1880. 392 pp., 8vo.; three Appendixes, two wood cut illustrations and six plates. By *N. H. Winchell.* Containing field descriptions of 442 crystalline rock samples, and notes on their geological relations, from the northern part of the state, new brachiopoda, the water supply of the Red River valley, and simple tests of the qualities of water; with reports on the Upper Mississippi region, by *O. E. Garrison;* on the Hydrology of Minnesota, by *C. M. Terry;* on the Glacial Drift and its Terminal Moraines, by *Warren Upham*; Chemical Analyses, by *J. A. Dodge;* a list of the Birds of Minnesota, by *P. L. Hatch;* and of the Winter Birds, by *Thomas S. Roberts.* Also in the Regents' Report for 1879 and 1880. Out of print.

The Tenth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1881. 254 pp., 8vo.; with ten wood cut illustrations and fifteen plates. By *N. H. Winchell.* Containing field descriptions of about four hundred rock samples, and notes on their geological relations, continued from the last report, the Potsdam sandstone; typical thin sections of the rocks of the Cupriferous Series; and the deep well at the "C" Washburn mill, Minneapolis; with Geological notes, by *J. H. Kloos;* Chemical Analyses, by *J. A. Dodge;* and papers on the Crustacea of the fresh waters of Minnesota, eleven plates, by *C. L. Herrick.* Also in the Regents' Report for 1881 and 1882.

The Eleventh Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1882. 219 pp., 8vo.; with three wood cut illustrations and one plate. By *N. H. Winchell.* Containing a report on the Mineralogy of Minnesota, and a note on the age of the rocks of the Mesabi and Vermilion iron districts; with papers on the crystalline rocks of Minnesota, by *A. Streng* and *J. H. Kloos*; on rock outcrops in Central Minnesota and on Lake Agassiz, by *Warren Upham;* on the iron region of Northern Minnesota, by *Albert H. Chester;* Chemical Analyses, by *J. A. Dodge;* and an Appendix containing Minnesota Laws relating to Mines and Mining, abstracted by *C. L. Herrick.* Also in the Regents' Report for 1881 and 1882.

The Twelfth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1883. Summary report, containing palæontological notes, and a paper on the comparative strength of Minnesota and New England granites, twenty-six pages, by *N. H. Winchell;* final report on the Crustacea of Minnesota, included in the orders Cladocera and Copepoda, 192 pages and 30 plates, by *C. L. Herrick;* and a catalogue of the flora of Minnesota, 193 pages, with ore map showing the forest distribution, by *Warren Upham.* Also in the Regents' Report for 1883 and 1884.

The Thirteenth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1884. 196 pp. Geological reconnoissances, the Vermilion iron ores, the crystalline rocks of Minnesota and of the Northwest, the Humboldt salt-well in Kittson county, records of various deep wells in the state, fossils from the red quartzyte at Pipestone, reports on the New Orleans Exposition and on the General Museum, by *N. H. Winchell;* Geology of Minnehaha county, Dakota, by *Warren Upham;* Chemical report, by *Prof. Jas. A. Dodge;* Minnesota geographical names derived from the Dakota language, by *Prof. A. W. Williamson;* insects injurious to the cabbage, by *O. W. Oestlund;* Geological notes in Blue Earth county, by *Prof. A. F. Bechdolt;* and on a fossil elephant from Stockton, by *Prof. John Holzinger;* papers on the Cretaceous fossils in the boulder clays in the Northwest, by *George M. Dawson* and by *Woodward* and *Thomas;* and notes on the Mammals of Big Stone lake and vicinity, by *C. L. Herrick.*

The Fourteenth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1885. 354 pp.; two plates of fossils and two wood cuts. By *N. H. Winchell.* Containing summary report, notes on some deep wells in Minnesota, descriptions of four new species of fossils, a supposed natural alloy of copper and silver from the north shore of Lake Superior, and revision of the stratigraphy of the Cambrian in Minnesota, with the following papers by assistants, viz.: List of the Aphididae of Minnesota, with descriptions of some new species by *O. W. Oestlund;* Report on the Lower Siberian Bryozoa, with preliminary descriptions of some new species by *E. O. Ulrich;* Conchological notes, by *U. S. Grant;* Bibliography of the Foraminifera, recent and fossil, by *Anthony Woodward.*

The Fifteenth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1886. 493 pp.; 8vo.; 120 diagram illustrations and sketches in the text, and two colored maps; embracing reports on observations on the crystalline rocks in the northwestern part of the state, by *Alexander Winchell, N. H. Winchell* and *H. V. Winchell;* Chemical report by *Prof. J. A. Dodge;* additional railroad elevations by *N. H. Winchell;* list of Minnesota geographical names derived from the Chippewa language, by *Rev. J. A. Gilfillan*, and notes on Illæni, describing three new species, by *Aug. F. Foerste.* Also as supplement II of the Regents' Report for 1887-1888.

The Sixteenth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1887. 504 pp.; 8vo.; two plates and 83 other illustrations. Contains reports on the original Huronian area, the Marquette iron region, on the Gogebic and Penokee iron-bearing rocks, on the formations of Northeastern Minnesota (including the physical aspects, vegetation, quadrupeds and other vertebrates), the geology of the region northwest from Vermillion lake to Rainy lake and of the Little and Big Fork rivers; also notes on the Molluscan fauna of Minnesota.

II. FINAL REPORT.

The Geology of Minnesota. Vol. I of the Final Report. 1872-1882. xiv. and 697 pp., quarto; illustrated by 43 plates and 52 figures. By *N. H. Winchell*, assisted by *Warren Upham*. Containing an historical sketch of explorations and surveys in Minnesota, the general physical features of the state, the building stones, and the Geology of Houston, Winona, Fillmore, Mower, Freeborn, Pipestone, Rock and Rice counties, by *N. H. Winchell;* the Geology of Olmsted, Dodge and Steele counties, by *M. W. Harrington;* and the Geology of Waseca, Blue Earth, Faribault, Watonwan, Martin, Cottonwood, Jackson, Murray, Nobles, Brown, Redwood, Yellow Medicine, Lyon, Lincoln, Big Stone, Lac qui Parle and Le Sueur counties, by *Warren Upham.* Distributed gratuitously to all public libraries and county auditor's offices in the state, to other state libraries and state universities, and to leading geologists and scientific societies; the remainder are held for sale at the cost of publication, $3.50 per copy in cloth, or $5 in grained half roan binding upon application to Prof. N. H. Winchell, Minneapolis.

The Geology of Minnesota. Vol. II of the Final Report. 1882-1885. xxiv. and 695 pp., quarto; illustrated by 42 plates and 32 figures. By *N. H. Winchell*, assisted by *Warren Upham*, containing chapters on the Geology of Wabasha, Goodhue, Dakota, Hennepin, Ramsey and Washington counties, by *N. H. Winchell*, and on Carver, Scott, Sibley, Nicollet, McLeod, Renville, Swift, Chippewa, Kandiyohi, Meeker, Wright, Chisago, Isanti, Anoka, Benton, Sherburne, Stearns, Douglas, Pope, Grant, Stevens, Wilkin, Traverse, Otter Tail, Wadena, Todd, Crow Wing, Morrison, Mille Lacs, Kanabec, Pine, Becker and Clay counties, by *Warren Upham.* Distributed according to law in the same manner as Vol. I above.

III. MISCELLANEOUS PUBLICATIONS.

1 Circular No. 1. A copy of the law ordering the survey, and a note asking the co-operation of citizens and others. 1872.

2. Peat for Domestic Fuel. 1874. Edited by *S. F. Peckham.*

3. Report on the Salt Spring Lands due the State of Minnesota. A history of all official transactions relating to them, and a statement of their amount and location. 1874. By *N. H. Winchell.*

4. A Catalogue of the Plants of Minnesota. Prepared in 1865, by *I. A. Lapham*, contributed to the Geological and Natural History Survey of Minnesota, and published by the State Horticultural Society in 1875.

5. Circular No. 2. Relating to botany, and giving general directions for collecting information on the flora of the state. 1876.

6. Circular No. 3. The establishment and organization of the Museum. 1877.

7. Circular No. 4. Relating to duplicates in the Museum and exchanges. 1878.

8. The Building Stones, Clays, Limes, Cements, Roofing, Flagging and Paving Stones of Minnesota. A special report by *N. H. Winchell.* 1880.

9. Circular No. 5. To Builders and Quarrymen. Relating to the collection of two-inch cubes of building stones for physical tests of strength, and for chemical examination, and samples of clay and brick for the General Museum. 1880.

10. Circular No. 6. To owners of mills and unimproved water-powers. Relating to the Hydrology and water powers of Minnesota. 1880.

IV. BULLETINS.

No. 1. History of Geological Surveys in Minnesota. By *N. H Winchell.*

No. 2. Preliminary Description of the Peridotytes, Gabbros, Diabases and Andesytes of Minnesota. By *M. E. Wadsworth.*

No. 3. Report of work done in Botany in the year 1886. By *J. C. Arthur.*

No. 4. A Synopsis of the Aphididæ of Minnesota. By *O. W. Oestlund.*

No. 5. Natural Gas in Minnesota. By *N. H. Winchell.*

The Tenth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1881. 254 pp., 8vo.; with ten wood cut illustrations and fifteen plates. By *N. H. Winchell.* Containing field descriptions of about four hundred rock samples, and notes on their geological relations, continued from the last report, the Potsdam sandstone; typical thin sections of the rocks of the Cupriferous Series; and the deep well at the "C" Washburn mill, Minneapolis; with Geological notes, by *J. H. Kloos;* Chemical Analyses, by *J. A. Dodge;* and papers on the Crustacea of the fresh waters of Minnesota, eleven plates, by *C. L. Herrick.* Also in the Regents' Report for 1881 and 1882.

The Eleventh Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1882. 219 pp., 8vo.; with three wood cut illustrations and one plate. By *N. H. Winchell.* Containing a report on the Mineralogy of Minnesota, and a note on the age of the rocks of the Mesabi and Vermilion iron districts; with papers on the crystalline rocks of Minnesota, by *A. Streng* and *J. H. Kloos*; on rock outcrops in Central Minnesota and on Lake Agassiz, by *Warren Upham;* on the iron region of Northern Minnesota, by *Albert H. Chester;* Chemical Analyses, by *J. A. Dodge;* and an Appendix containing Minnesota Laws relating to Mines and Mining, abstracted by *C. L. Herrick.* Also in the Regents' Report for 1881 and 1882.

The Twelfth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1883. Summary report, containing palæontological notes, and a paper on the comparative strength of Minnesota and New England granites, twenty-six pages, by *N. H. Winchell;* final report on the Crustacea of Minnesota, included in the orders Cladocera and Copepoda, 192 pages and 30 plates, by *C. L. Herrick;* and a catalogue of the flora of Minnesota, 193 pages, with ore map showing the forest distribution, by *Warren Upham.* Also in the Regents' Report for 1883 and 1884.

The Thirteenth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1884. 196 pp. Geological reconnoissances, the Vermillion iron ores, the crystalline rocks of Minnesota and of the Northwest, the Humboldt salt-well in Kittson county, records of various deep wells in the state, fossils from the red quartzyte at Pipestone, reports on the New Orleans Exposition and on the General Museum, by *N. H. Winchell;* Geology of Minnehaha county, Dakota, by *Warren Upham;* Chemical report, by *Prof. Jas. A. Dodge;* Minnesota geographical names derived from the Dakota language, by *Prof. A. W. Williamson;* insects injurious to the cabbage, by *O. W. Oestlund;* Geological notes in Blue Earth county, by *Prof. A. F. Bechdolt;* and on a fossil elephant from Stockton, by *Prof. John Holzinger;* papers on the Cretaceous fossils in the boulder clays in the Northwest, by *George M. Dawson* and by *Woodward* and *Thomas;* and notes on the Mammals of Big Stone lake and vicinity, by *C. L. Herrick.*

The Fourteenth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1885. 354 pp.; two plates of fossils and two wood cuts. By *N. H. Winchell.* Containing summary report, notes on some deep wells in Minnesota, descriptions of four new species of fossils, a supposed natural alloy of copper and silver from the north shore of Lake Superior, and revision of the stratigraphy of the Cambrian in Minnesota, with the following papers by assistants, viz.: List of the Aphididae of Minnesota, with descriptions of some new species by *O. W. Oestlund;* Report on the Lower Silerian Bryozoa, with preliminary descriptions of some new species by *E. O. Ulrich;* Conchological notes, by *U. S. Grant;* Bibliography of the Foraminifera, recent and fossil, by *Anthony Woodward.*

The Fifteenth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1886. 493 pp.; 8vo.; 120 diagram illustrations and sketches in the text, and two colored maps; embracing reports on observations on the crystalline rocks in the northwestern part of the state, by *Alexander Winchell, N. H. Winchell* and *H. V. Winchell;* Chemical report by *Prof. J. A. Dodge;* additional railroad elevations by *N. H. Winchell;* list of Minnesota geographical names derived from the Chippewa language, by *Rev. J. A. Gilfillan,* and notes on Illæni, describing three new species, by *Aug. F. Foerste.* Also as supplement II of the Regents' Report for 1887-1888.

The Sixteenth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1887. 504 pp.; 8vo.; two plates and 83 other illustrations. Contains reports on the original Huronian area, the Marquette iron region, on the Gogebic and Penokee iron-bearing rocks, on the formations of Northeastern Minnesota (including the physical aspects, vegetation, quadrupeds and other vertebrates), the geology of the region northwest from Vermillion lake to Rainy lake and of the Little and Big Fork rivers; also notes on the Molluscan fauna of Minnesota.

II. FINAL REPORT.

The Geology of Minnesota. Vol. I of the Final Report. 1872-1882. xiv. and 697 pp., quarto; illustrated by 48 plates and 52 figures. By *N. H. Winchell*, assisted by *Warren Upham*. Containing an historical sketch of explorations and surveys in Minnesota, the general physical features of the state, the building stones, and the Geology of Houston, Winona, Fillmore, Mower, Freeborn, Pipestone, Rock and Rice counties, by *N. H. Winchell;* the Geology of Olmsted, Dodge and Steele counties, by *M. W. Harrington;* and the Geology of Waseca, Blue Earth, Faribault, Watonwan, Martin, Cottonwood, Jackson, Murray, Nobles, Brown, Redwood, Yellow Medicine, Lyon, Lincoln, Big Stone, Lac qui Parle and Le Sueur counties, by *Warren Upham*. Distributed gratuitously to all public libraries and county auditor's offices in the state, to other state libraries and state universities, and to leading geologists and scientific societies; the remainder are held for sale at the cost of publication, $3.50 per copy in cloth, or $5 in grained half roan binding upon application to Prof. N. H. Winchell, Minneapolis.

The Geology of Minnesota. Vol. II of the Final Report. 1882-1885. xxiv. and 695 pp., quarto; illustrated by 42 plates and 32 figures. By *N. H. Winchell*, assisted by *Warren Upham*, containing chapters on the Geology of Wabasha, Goodhue, Dakota, Hennepin, Ramsey and Washington counties, by *N. H. Winchell*, and on Carver, Scott, Sibley, Nicollet, McLeod, Renville, Swift, Chippewa, Kandiyohi, Meeker, Wright, Chisago, Isanti, Anoka, Benton, Sherburne, Stearns, Douglas, Pope, Grant, Stevens, Wilkin, Traverse, Otter Tail, Wadena, Todd, Crow Wing, Morrison, Mille Lacs, Kanabec, Pine, Becker and Clay counties, by *Warren Upham*. Distributed according to law in the same manner as Vol. I above.

III. MISCELLANEOUS PUBLICATIONS.

1 Circular No. 1. A copy of the law ordering the survey, and a note asking the co-operation of citizens and others. 1872.

2. Peat for Domestic Fuel. 1874. Edited by *S. F. Peckham*.

3. Report on the Salt Spring Lands due the State of Minnesota. A history of all official transactions relating to them, and a statement of their amount and location. 1874. By *N. H. Winchell*.

4. A Catalogue of the Plants of Minnesota. Prepared in 1865, by *I. A. Lapham*, contributed to the Geological and Natural History Survey of Minnesota, and published by the State Horticultural Society in 1875.

5. Circular No. 2. Relating to botany, and giving general directions for collecting information on the flora of the state. 1876.

6. Circular No. 3. The establishment and organization of the Museum. 1877.

7. Circular No. 4. Relating to duplicates in the Museum and exchanges. 1878.

8. The Building Stones, Clays, Limes, Cements, Roofing, Flagging and Paving Stones of Minnesota. A special report by *N. H. Winchell*. 1880.

9. Circular No. 5. To Builders and Quarrymen. Relating to the collection of two-inch cubes of building stones for physical tests of strength, and for chemical examination, and samples of clay and brick for the General Museum. 1880.

10. Circular No. 6. To owners of mills and unimproved water-powers. Relating to the Hydrology and water powers of Minnesota. 1880.

IV. BULLETINS.

No. 1. History of Geological Surveys in Minnesota. By *N. H Winchell*.
No. 2. Preliminary Description of the Peridotytes, Gabbros, Diabases and Andesytes of Minnesota. By *M. E. Wadsworth*.
No. 3. Report of work done in Botany in the year 1886. By *J. C. Arthur*.
No. 4. A Synopsis of the Aphididæ of Minnesota. By *O. W. Oestlund*.
No. 5. Natural Gas in Minnesota. By *N. H. Winchell*.

36433

THE GEOLOGICAL

AND

NATURAL HISTORY SURVEY

OF MINNESOTA.

The Eighteenth Annual Report, for the year 1889.

N. H. WINCHELL,

State Geologist.

THE BOARD OF REGENTS

OF THE

UNIVERSITY OF MINNESOTA.

Hon. Greenleaf Clark, St. Paul,	1889
Hon. Cushman K. Davis, St. Paul,	1889
Hon. Knute Nelson, Alexandria,	1890
Hon. John S. Pillsbury, Minneapolis,	1890
Hon. Henry H. Sibley, St. Paul, *president*,	1891
Hon. Gordon E. Cole, Faribault,	1891
Hon. Wm. Liggett, Benson,	1891
Hon. William R. Merriam, St. Paul, the governor of the state,	*ex-officio*
Hon. David L. Kiehle, St. Paul, *recording secretary*, the superintendent of public instruction,	*ex-officio*
Cyrus Northrop, Minneapolis, *corresponding secretary*, the president of the university,	*ex-officio*

TREASURER OF THE UNIVERSITY.

Hon. H. P. Browne, - Address, Commercial Bank, Minneapolis, Minn.

CONTENTS.

Summary Statement for 1889, 3

Report of Field observations, N. H. Winchell,

Made in 1888.

On the Mesabi iron range, 7
About Tower, 8
At Ely, 12
Pokegama Falls and eastward, 13
Gold in the Keewatin in Northern Minnesota, 19
The crystalline rocks of the Minnesota valley, 22

Made in 1889.

At Duluth, 25
Iron mines at Tower, 27
The age of the gabbro, 43
Further observations on the typical Huronian and on the rocks about Sudbury, Ontario, 47
Additional rock-samples numbered, 59

American opinion on the older rocks, A. Winchell.

Introduction, 65
1. Ebenezer Emmons, 68
2. Douglass Houghton, 87
3. Edward Hitchcock, 92
4. Henry D. Rogers, 101
5. James Hall, 106
6. Sir William E. Logan, 112
7. Josiah D. Whitney, 140
8. Thomas Sterry Hunt, 150
9. George F. Matthew, 156
10. Charles H. Hitchcock, 157
11. Thomas Benton Brooks, 169
12. Newton Horace Winchell, 175
13. Carl Rominger, 188
14. Roland Duer Irving, 195
15. Andrew C. Lawson, 208
Index, 220
Additions to the Library of the Survey since 1884.
List of publications of the survey.

ADDRESS.

THE UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, March 3, 1890.

To the President of the University.

DEAR SIR: With the round of another year I herewith report the progress made in the geological and natural history survey of the state. During the year there has been considerable interruption incident to the removal and installment of the museum and survey headquarters in the new Science Hall. This was aggravated by the fire which unfortunately broke out in the building in the latter part of December, and which, while not consuming much, yet so damaged the rooms and their contents that it necessitated the renovation of the entire building, and the cleaning of most of the specimens and apparatus. This report gives an idea of the progress that is being made in the intricate geology of the northeastern part of the state, and of the economic resources that are being developed there. That part which discusses the iron ores of the state is planned to be published as a separate bulletin of the survey.—Bulletin No. 6. It is accompanied by numerous illustrations and a geological map.

Respectfully, your obedient servant,
N. H. WINCHELL,
State Geologist and Curator of the General Museum.

REPORT.

I.

SUMMARY STATEMENT FOR 1889.

There was not much field-work done in 1889. This was due to the change from field-work to office and laboratory work which was announced in the last annual report incident on the commencement of the final report on the northern part of the state. In July, however, a special reconnoissance was made of the iron-deposits and the mines at Tower and Ely, in order to get some details of the relations of the ore-bodies to the country rock as developed about the works, and of the methods of mining and transportation. In some directions this review was extended into the surrounding country whenever there was promise of new facts either economic or scientific. This re-examination resulted in the acquirement of of many interesting facts of detail, and in the establishment or the rejection of some hypotheses as to the origin of the ore bodies, and the genetic history of the rocks embracing them. It was thought that with the light of the field observations made during the previous three years fresh in mind, and with all the known theories of the ore and of the general geology that had been proposed whether by the Minnesota survey or by others, immediately and continually under test and application, such a careful investigation would be a valuable preparation for the discussion of the crystalline rocks which was contemplated, and especially for the exposition of the iron ores contained in Bulletin No. 6. This review was made in conjunction with Mr. H. V. Winchell; and inasmuch as the progress of the investigation here, as elsewhere, has been frequently the result of our joint work and mutual co-operative study, the bulletin devoted to the iron ores herewith transmitted bears our joint authorship.

Within the past year two other bulletins have been published, viz., *Natural Gas in Minnesota*, and *The History of Geological Surveys in Minnesota.*

The Legislature of 1889 failed to make provision for the publication of the two final volumes of the survey report referred to in the last annual statement. This failure, however, was not due so much to indifference on the part of the Legislature as a whole, as to the unfriendly manipulation of some of the committees, and the neglect of the public officials having in charge the estimates and recommendations for the current expenses. The reports of the survey were eagerly sought by all the legislators, both for themselves and for their friends. They were aggrieved when they found that by law this distribution was not wholly gratuitous and instant, and they desired the publication of the final volumes as fast as they can be got ready. The bill for a law, however, making provision by a money appropriation for the printing of the manuscripts now on hand was delayed by the chairman of the committee having it in charge until it was too late to get the appropriation allowed by the general finance committee and acted on by both houses of the Legislature. The same will be offered for publication at the next session of the Legislature (1891).

In the summer of 1889 the museum and all the paraphernalia of the survey were removed from the "main building" of the University, where it has been located since 1872, to the new Science Hall. The building was not yet completed, but the removal had to be made to give opportunity to fit the old rooms for other use prior to the opening of the fall term of the University. The building was nearly finished, and some work had been given to the museum and to the equipment of the various rooms, and plans had been entered upon for office and laboratory work, when another interruption was suffered (Dec. —) by the (supposed) spontaneous starting of a fire in the engine room, where painters had been at work with naphtha and white lead. This kept the survey work largely in abeyance till about Feb. 15, 1890, when the building had been again sufficiently restored, and the damaged rooms renovated, to permit of their regular occupancy. Thus it will be seen that the work of more than six months has been so broken and unsatisfactory that it will not permit a very cheerful view to be taken of the aggregate progress of the year. Still, unless some other unfavorable cause interfere, the commodious rooms now occupied by the survey for office, drafting room, laboratories, museum and storage, will, when fully equipped with apparatus, and the library with reference books, warrant the expectation that the nicer researches that remain to be done in order to "finish" the survey of the state, will go forward with ease and dispatch.

The Museum now needs replenishing. The room that is given to it is more than four times as large as that which it occupied in the other building, and numerous new cases ought to be constructed.

This is true particularly of the zoological collections, which have been put in the special charge of professor Nachtrieb. In the geological museum, while the old cases have been refitted and made to answer for the present, there is a need of mineralogical specimens and there will be soon need of other cases for exhibition. Some of the specimens of the Kunz collection purchased in 1876 have been lost. Many of them are permanently removed from exhibition in the museum and stored in the geological lecture room. Indeed many of the unique and attractive specimens formerly kept in the museum for exhibition have been missing from their places from that cause for some years, and some have been badly damaged. The mineral collection has thus inevitably deteriorated, and ought to be replenished by occasional purchase. Of course donations aid in keeping the collections (i. e. the cases) apparently full, but donations do not supply first-class material.

State Park. I wish to call the attention of the regents, and through their report, the attention of the public and the Legislature to the propriety of asking a reservation of land for a state park in some section in the northern part of the state. The geographic positon of Minnesota is on that border land which exhibits the transition of the forested area into the prairie. It hence preserves the faunal and floral characteristic of both, and within its territory must be studied by naturalists the mutual modifications and interchanges which the near neighborhood and contact of different physical features always imprint on the native vegetation and animal life found therein. By settlement and long habitation the natural conditions are destroyed and the natural laws that could perhaps be discovered by an examination of them in their original state, are never known. Hence as long as the natural conditions exist the state of Minnesota will be visited by students and collectors interested in natural science for the purpose of investigation, and this will bring Minnesota into prominent recognition in scientific literature and secondarily into scientific and economic research. It hence behooves the State to preserve, to such extent as may be found desirable and feasible, these natural and aboriginal conditions, and for this purpose there is no better method than to reserve from sale and settlement some considerable tract where they may not be destroyed.

Again the state should have a large public park because of the healthful resort that it ould afford for those living in cities, and for those who, coming from further south, seek in summer the invigorating effect of northern latitudes. The attractions of a multitude of lakes, rivers and rivulets of limpid and pure water, are confined in the United States, to the northern tier, where the tumuli of the glacial epoch formed the depressions and natural reservoirs of gravel and sand, such as mark its moraines from Maine to Minnesota. In Dakota these lines of tumuli pass across the prairies northwestward to the line of British America and do not return again sensibly within the United states, Hence it is within Minnesota that exists the last opportunity to preserve the pristine conditions of that unique combination of physical and faunal relations which alike distinguishes them from all other natural surface conditions in the United States, and has attracted to them always the venturesome, wandering explorer, the artist, the geologist, and the hardy frontier settler.

This park should be located either in the region northeast of lake Superior, enclosing some of the rock-bordered and rock-bottomed lakes that are a natural curiosity to every traveler, or in the area about the head waters of the Mississippi. General J. H. Baker, when surveyor-general of Minnesota, some years ago, urged that such a park be established on the international boundary line north of lake Superior, and specified the region of lake Saganaga. Since then, the region of the Itascan source of the Mississippi river has come into prominence, and it has served as the topic of several explorations and new "journals," which have given it already a renown equal to the earlier historic interests that cling to it since the days of Lieut. Allen, of H. R. Schoolcraft and Jean Nicollet. These artificial elements enter strongly into the question of making the selection for a state park, and bear heavily in favor of the sources of the Mississippi for such a selection. There is, fortunately, a perfect exemplification of the natural surface features that characterize the glacial moraines of the state within a few miles of the Itasca lake, and, indeed, they give outline and location to the entire Itascan basin, and would thus serve to embrace, within easy access or in combination, both the natural and the artificial considerations. This region is, moreover, remote from lake Superior, and its attractions, by contrast with the surrounding country, would be hightened in the mind of every visitor. Whereas, in the northeastern part of the state, lake Superior and its attendant waters and surrounding hills, dominate the district, so that no selection could be made whose attractions would rise above those of the great lake itself.

It is presumed that there would be no difficulty, whether in the northeastern or the northwestern part of the state, or even in both, in getting the consent and cooperation of the United States government by the withdrawal of the lands concerned from the market, and perhaps of any private parties who may have received some of the lands from the United States, or from the State of Minnesota. At any rate, no time should be lost in entering upon the project, because of changes and increased difficulties that will render it impossible not many years hence.

The laboratory and office of the survey ought to be supplied with apparatus and books needed for the work that lies immediately before it. This is a matter of absolute necessity. It were better that all other expenses cease entirely till there be sufficient funds for this necessity, or that a special appropriation be made by the Legislature to provide them.

II.

Record of Field-Observations in 1888.

On the Mesabi Iron Range. Mallmann's mining camp is on the Duluth and Iron Range railroad, about two miles south of Hinsdale on the Giant's range of granite hills. The working is for iron ore. There are a number of pits or shafts sunk to the rock, from 15 to 50 feet in depth, and they have uniformly encountered the same magneto-bedded rock that Chester did on the Mesabi range a few miles further northeast[*] and of a character identical with that seen near the west end of Gunflint lake,[**] both being a part of the Animike, and probably in the lower portion of it. About half a mile further south is a cut by the railroad in real Animike slate. Some of the ore he finds is hematite, and he hopes to get enough that is hematite to warrant his enterprise. This working is just west from the "red cut" which is mentioned in the 13th report in giving a description of a trip to Tower, and in one of the shafts he has struck this red hematite mass. The rock seems to be more rotted in this red mass.

This magneto-bedded rock is nondescript. It has been referred to sometimes as quartzyte, but it generally contains not enough free quartz to entitle it to that designation. It is gray, medium-grained, sometimes fine-grained, has a mineral, apparently a feldspar, that changes by rot to a white kaolinic substance, or to a rusty powder, and is the rock in which is scattered the magnetite ore both here and at Gunflint lake, as well as at Chub (Akeley) lake. This ore is in lenticular bunches, elongated in the direction of the general bedding, and is generally not pure magnetite, but is seen to increase and fade again in the midst of the rock, sometimes extending in parallel bands from half an inch to an inch wide, and a foot or more in length. It is this same rock which accompanies the hematite, which inspires Mallmann with fresh hope. Apparently the hematite is disseminated in it in the same way as the magnetite. Mallmann is confident the ore here is the same as the ore mined at Tower, and in the same kind of rock—a mistake which we tried to correct. There is no question but the vertical greenish schists and graywackes seen at the Tower mines are repeated south of the Giant's range, and pass uncomformably below the Animike along the line of strike all the way from Gunflint lake to this point, and that they may be encountered after passing through the slates and quartzytes of the Animike. It is likely also that they are as apt to carry iron-ore lenses on the south side of that range as on the north side. But owing to the prevalence of the drift, and the concealment of these schists by the overlapping of the Animike, it would be a herculean and problematical task to seek to find such ore bodies by shafting through the Animike. It would not be impossible that a shaft should go down through the Animike, and should encounter one of these ore bodies in the Keewatin, but the chances against such an event would be many thousands to one. It is probable therefore that all the ore found by Mallmann here is from the Animike beds.

---

[*] See Eleventh Annual Report, p. 156

[**] See Sixteenth Report, pp. 80, 267.

Observations about Tower. We visited again the verticel black slaty crag north of Tower, in the southern slope of the south ridge (photographed in 1886), and noted the abrupt and uncomformable transition from the slate to the green schist. This occurs a little west from the crag, and in a lower place. There is no indication that either underlies or overlies, as the line of contact is on a nearly horizontal plane surface. The structure and bedding of the slate is interrupted somewhat obliquely by that of the schist, and shows plainly some kind of unconformity. This slate is siliceous and has all the banding of the jaspilyte, but is not colored. A little further north it is like jaspilyte. Indeed, it passes into the rock which is, or which becomes, or which embraces the ore.

Thence we went further west and after considerable search we found the low, bare, slaty knoll, consisting of fissile slate, which was mentioned in the report of **1886, in which was recorded a gradual passage from the clay slate to the chlorite slate of the region. We examined it to find sedimentary banding. While this banding is not, in the knoll, characteristically exhibited, yet there are some long, parallel, color-bands, about one-sixteenth to one-half inch wide, that appear to be due to sedimentary action. It is noteworthy that throughout this knoll of clay slate, generally no such bands are visible. This may be due to the shattered condition of the rock and the obliteration of an original structure by the process of acquiring the slatiness. Toward the east, the slate, followed along the strike, *evidently gets more and more siliceous*, till, after some intervals of non-observation due to drift and to brush, it is converted into jaspilyte, first passing through the condition of the slate crag described above. But there is in the midst of this slate, further east, a little greenish, coarse sericitic and quartzose slaty-rock (No. 1505), apparently alternating with the clayey slate, which may be the parallel of the schist seen to alternate with the jaspilyte rock, as at the railroad cut south of the Stone mine. This indicates that, as formerly supposed, there is a close alliance between the clay slate and the green schist, or at least *a schist* which cannot with any certainty *or satisfaction be distinguished from it*, and again an alliance that implies some community of origin and structure between all three of these schists. In following the strike along toward the east from this knoll we saw a bed about fourteen inches thick of such green schist (but rather darker and coarser grained), *imbedded in the jaspilyte**. The lack of sedimentary signs (*i. e.*, the general lack) caused me to query whether the eruptive green schists could become changed to argillyte, but on finding some, not very distinct, trace of bedding, and especially on seeing the argillyte bed change, in the direction of its strike, apparently first to siliceous slate and then to jaspilitic beds, the conclusion is found inevitable that the argillyte at least is an originally sedimentary rock.

---

*Compare H. V. Winchell's report on this region, 17th report, pp. 88-9.

**Fifteenth report, p 267.

But this leaves to still be accounted for the green (or gray when siliceous) schist which usually resembles closely the green schist which is supposed to be of originally eruptive origin, seen interbedded with the argillyte. On the suppositions that it is of identical genetic origin with the eruptive green schist, it may be supposed to have been brought there by slight eruptions at the time of the sedimentation of the argillyte, and that would rather require that all the supposed eruptive green schist which embraces the jaspilyte, originated in the same way, *i. e*, in a manner similar to the eruptive sheets of the Cupriferous, and is now interbedded in the great (Keewatin) formation, as schists, in the same manner. This would make the eruptive green schists date from the time of the Keewatin itself, and the green schists would be found to be, on a large scale, conformable with the adjacent rock, instead of being of the nature of later overflows and uncomformable with it. The latter supposition was expressed in the 15th annual report.* I do not know that there is any necessary and known objection to that hypothesis. It would be necessary still to account for the rock having now the condition and structure of a schist and for its being sometimes the matrix for a multitude of fine pebbles of jaspilyte.

---

*Compare Bulletin No. 6, where such a layer of silicious green schist is described on the north slope of the "north ridge," embraced in the contorted jaspilyte.

But it is not by any means certain yet that this gray schist (1505) is identical with, or can be found to grade into, the great body of green schist of the region, so that they can be embraced in the same general hypothesis.

We went over the south ridge at the Lee mine and west from there, and the following facts were noted:

1. In some places the jaspilyte is wonderfully brecciated over large areas, the same parts again cemented by the ferruginated granular silica, or by the same in a finer breccia, so that the general mass is as hard as the jaspilyte unbroken, and in this condition shows large glaciated areas.
2. When broken less minutely the cement is, in some other places, pure hematite, and when this has accumulated in large enough masses, filling pre-existing cavities whose forms it takes on, it is valuable as ore, and as such is the principal basis of the working of the Lee mine.
3. This accumulation of hematite, or re-cementation, took place before the deposition of any vitreous silica, or before any observable "silicification."
4. Chemical (*i. e.*, vitreous) silica was afterward deposited in openings and geodes in this hematite, and in veins crossing both the hematite and the jaspilyte, this being the last observable step.
5. I do not see hematite veins crossing chemical silica veins.
6. Hematite veins cross jaspilyte in all its forms, whether in breccia or as undisturbed strata in the jaspilyte.
7. Chemical silica veins and nodules occur latest and cross the hematite and also the jaspilyte.

This seems to show that there were two processes after the deposition of the original sediments forming the jaspilyte, viz., a ferruginization and a silicification, and that the former preceded. But, as already argued in the fifteenth report, the chalcedonic silica was not concerned in either of them, except that the rounded grains have become angular by deposition of interstitial silica. Samples 1506 show the relations of the chemical silica to the hematite, and 1507 show the brecciated jaspilyte cemented by a finer breccia of the same.

---

*Page 221, 269, 322.

On Chester Peak (or Jasper Peak, so generally called at Tower), on the northwest side and shoulder, the jaspilyte dips north at an angle of about eighty degrees. It suddenly changes and dips west at seventy-five degrees, then as suddenly changes and dips east at seventy-five degrees. It then veers round on the apex of the hill so as to dip northeast at seventy degrees. In the easterly part, which is lower, the dip is north again. The hill is abrupt and short, but elongated about east and west. A stretch of drift, like a morainic ridge, rising about fifty feet, connects the hill with the "north ridge," in which are the mines of the Minnesota Iron Company; but there seems to be no rock-ridge uniting them. The "north ridge" dies out toward the east, although a series of low hills, making a lower range, can be seen to run along the south side of Vermilion lake and eastward. Toward the south the range of the Giant's hills can be seen from where it rises, on the south side of Birch lake to where they run out in the distance toward the west. They have openings and sudden elevations, but are without any notable peaks, the highest and apparently the most important hills being toward the southwest rather than south.

Numerous pits have been sunk by the iron company to the rock in the vicinity of this peak, and between it and the "north ridge". Some of them strike green schist, some a jaspilyte without ore, or a lean ore, and some of them reveal good ore. But in one of them, at the northwestern base of the peak, a black schist, soft and (carbonaceous?) holding balls of pyrite (1508) from a bullet's size to two and a half inches in diameter, was met in the bottom of the shaft. On the northern face of this hill are the green schists, seen at the mines, mixed and twisted with the jaspilyte. A deep drill hole on the south side of this hill afforded the diamond drill a core of porphyrel at several hundred feet below the surface, the hole sloping north.

Glaciated surfaces are seen nearly to the top, and a few boulders lie on the very top.

Some small veins in the brown jaspilyte consist of white chalcedonic silica (1509) crossing the jaspilyte banding. In the immediate vicinity are deposits of chemical silica. The existence of chalcedonic veins is a very rare occurrence, and has been observed, though doubtfully, but once before. Compare the fifteenth report, p. 324, and rock sample 1013. There must be some way to account for these chalcedonic veins. They do not appear to have been formed by mechanical transposition of laminæ in or across the jaspilyte strata. They do not have any banding or crystallization like true veins. They form a network connecting a coarse (and in some places a fine) breccia of brown fine-laminated jasper. These are on the exposed upper surface of the glaciated apex of the knob. The silica is white, and appears to have the effect and disposition of vein matter but not its structure. This hill is in nw ¼ ne ¼ sec. 35, 62-15.

At Ely. The rock-cuts all the way from Tower to Ely, so far as seen from the train, are all in the green schist, or a green rock more massive than schist which imperceptibly takes its place, and at Ely is the rock which has there been described in the field-observations of 1886 (Fifteenth Report, pp. 325-26), and which extends from Ely to the shore of Shagawa (Long) lake, and really which goes also to Fall lake and there forms the falls. At the railroad cut at Ely it exhibits some new features, viz:

1. It is made up of rounded masses of itself, or rock like itself, some of them four feet across, and some not more than three inches.
2. The rock matter between the rounded masses is darker green than the rounded boulders, and squeezes among them in the same manner as green schists between jaspilyte boulders at Tower. It is also more apt to be a little schistose.
3. There is no bedding like sedimentation, but an angular coarse jointage like that of eruptive rock which has flowed in a broad sheet over the surface. The forms of these boulders are visible in the weathered surface, and their slickensided (and then darker) exteriors are shown on the face of the railroad cut.
4. The boulders are frequently amygdaloidal, calcite being the mineral enclosed; but the cavities are rendered conspicuous by the easy weathering out of the calcite.
5. There is a crust of somewhat darker rock that surrounds the interior of the boulders, and these cavities are most abundant in it; they are commonly in the form of tubes that cross this crust approximately at right angles, radiating as from the centre, though not reaching the centre. Transverse to these tubes this crust sometimes exhibits a dim linear structure that appears to be fluidal.
6. This green rock contains chalcedonic silica, disseminated all through it, and it seems to result from a change in the chemical silica
7. This green rock is of the same genetic nature, and the same in all its physical aspects, with the exception of such as can be referred to difference of weathering, as the Stuntz Island conglomer-

ate, but the enclosed boulders are less siliceous than the most of those in that conglomerate.

8. The rock that embraces these boulders is not usually, but is rarely, amygdaloidal. This is the rock which I designated, in this vicinity last year (1887), and before*, as modified graywcake, but it seems now never to have been in the form of graywacke.

No. 1510 is a sample of this green rock, showing the forms of two boulders, and the darker-green rock separating them.

No. 1511 contains amygdaloidal portions of some of the boulders, showing the tubes perpendicular to the surface, one specimen having a glaciated surface. (Compare Plate 1, Sixteenth Annual report).

No. 1512 has chalcedonic silica from veins and spots in the rock 1510.

No. 1513. Vein matter in No. 1510, similar to 1501 which is from the so-called gold-quartz vein at Eagle Nest lake.

In returning from Ely to Tower the conglomeratic (or agglomeratic) character of the green stone was more frequently noticed at the occasional cuts. The rock is angularly and cuboidally jointed in most of the cuts, with a light green color, weathers lighter, but in some cuts it is a schist with a slaty tendency in disintegration, and has doubtless been called sericitic schist in many places.

Southward from Tower this rock continues, as seen from the train, as far as nearly to the gneiss exposures that appertain to the northern flank of the Giant's range. It has been reported by H. V. Winchell** that there is no exposure of mica schist between its last exposure and the first of the gneiss. There is an unobserved interval, however, between the two amounting to about two miles in which there may still be a narrow belt of mica schist.

[NOTE. In the spring of 1890 a belt of mica-hornblende schist was exposed in some railroad cuts, a few miles north of the Giant's range syenite.]

Pokegama Falls and eastward to Griffin's camp. At the falls of Pokegama the dip of the quartzyte was carefully measured at several points, with the following results: Below the falls, S. 8° W. about 15 degrees; above the falls, S. 8° E. about 15 degrees; at the bluff, on the west side of the river, a sixth of a mile above the falls, S. 22° E. 8 degrees.

The rock is quartzyte, red superficially (from six to twelve inches) and gray within. The bluff above mentioned is 27 feet high above the water, and the beds composing it seem to strike southeastward to the falls. Mr. Griffin says this rock runs under the river which is the outlet to Pokegama lake, and used to cause rapids at half a mile below the lake, in Sec. 23, T. 55-26. But now these rapids are covered by the setting back of the water into the lake from the Mississippi from the government dam, which is built just above the falls. He also says he thinks he saw once (as surveyor) an outcrop of it on Little Boy river, about in the line of strike from Pokegama falls. H. V. Winchell also reports having seen it on Little Boy river. Mr. Griffin also is authority for an outcrop of the same rock about eight miles southwest from Pokegama falls. In 1871 or 1872, as deputy surveyor, he also noted the same rock north from Sugar lake (two or three miles) in Sec. 6 or 31. This rock appears to be the Pewabic quartzyte, so named much further northeast on the southerly slopes of the Giant's range.

---

*Fifteenth report, p. 326.

**Seventeenth report, p. 89.

October 18, 1888. In the rain (there was a drizzling rain all the rest of the day) we went to the falls of Prairie river, first seeing the granite at the upper falls.

There is a large display here of gray gneiss, some of it being micaceous, and some of it having hornblendic, dark masses and belts cutting through it. In some rare places it is laminated in thin indistinct laminæ of mica and feldspathic sheets. Its dark belts and isolated masses recall the rock at Morton, on the Minnesota river (see another section of this year's report) and north of Vermilion lake, but there being so little of this it will not be correct to parallelize it with the mica-hornblende series. It is rather the extension of the Giant's range rocks, which are mostly without noticeable micaceous or dark hornblende laminations, and generally a more massive rock than the micaceous gneisses of the Vermilion series. At one point on the west bank of the river there is a rude horizontal, undulating stratification or bedding. On the east bank opposite this, however, the gneiss is conspicuously basaltically jointed It is probable, therefore, that the former may be due to weathering upon a spot where by a shearing pressure a local lamination had been superinduced. There are also in some places in the gneiss, thin alternations with a shining micaceous schist running about horizontal, such that the general aspect and average composition is quite different from the rock in general (see No. 1523). Red orthoclastic belts (1524) more coarsely crystalline, containing also coarse quartz crystals, run irregularly through the mass. In one spot a wedge of reddish rock, associated with chlorite, making a (protogine?) runs through it.

We do not see the contract of this gneiss with the overlying quartzyte. The latter is seen at the lower falls and while dipping in the main to the s. s. e. about 10 degrees (sometimes 12 degrees) it undulates in one or two synclinals. Along the top of one of the anticlinals can be seen a distinct fracture, opening somewhat upward, as the crest runs across the river.

Glacial marks here run S 10° E. (mag.) and Mr. Griffin says there is no magnetic variation here.

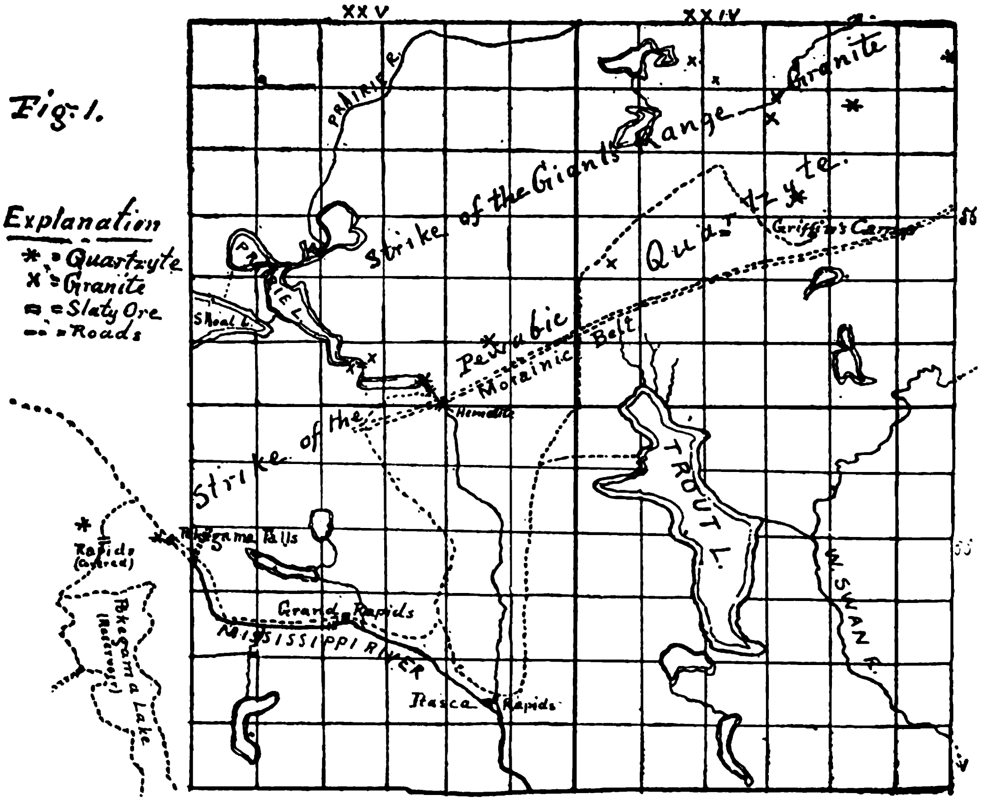
No. 1525 (a) represents an incipient or pseudo-amygdaloidal spottedness in this quartzyte, which may be allied to that lately described by Bailey at Pigeon Point.

No. 1526 shows another spottedness in this quartzyte, the rusty spots weathering out and making the surface pitted all over.

No. 1527. So far as can be seen then comes on toward the south (after an unexposed interval) a lot of siliceous and hematitic cherty beds, the hematite in some cases being fine, massive, nearly pure, and finely basaltically jointed. These beds are seen only about five feet in thickness, and the hematite is apparently not more than six inches. No. 1528 represents some of the rock about at the horizon of this hematite. No. 1529 somewhat above (in the beds). No. 1528. This shows a curious "streamed" mixture, and brecciated bed of chalcedonic silica, jasper and hematite, with vitreous glassy silica filling veins or former geodic elongated cavities that are embraced entirely in a casing of white chalcedonic silica. The highest part is represented by 1530, which has a very different aspect from 1529, being a coarser, evidently fragmental, rusty, siliceous, somewhat vesicular rock, but yet may be only a modified condition of 1529. It has pure hematitic sheets and lumps, and is, in general, bedded, and dips conformably with the quartzyte below, in beds fron six to ten inches thick. It is mainly a felsyte with hematite, some of the beds having the bloodstone distribution seen in some at the east end of Gunflint lake. Some of the quartzyte that underlies is conglomeritic (1532) in patches, but it is not seen so in any continued layers.

In making the trip from Grand Rapids to Griffin's camp (see sketch-map, fig. 1, p 16),we traveled eighteen miles over an execrable road in an autumn snow storm which not only kept our clothing wet but loaded every bush with dripping snow and water. As we had been in the rain the greater part of the previous day, and returned the following day in a snow storm of the same kind but somewhat cooler air, we found the three days productive of results not entirely geologic.

Fig. 1.



The trip was very useful in a geological sense, but it cannot be said to have afforded sufficient evidence to answer the question of the true relation of the Pewabic quartzyte to the black slate of the Animikie. So far as the evidence goes, *unless there be two great quartzytes*, it seems to indicate that the Pewabic quartzyte overlies the black slate, although it is next in contact with or adjoining the granite all along the south side of the Giant's range and as far west as to Pokegama falls, at the latter place the quartzyte being separated from the gneiss by an unexposed interval of unknown strata, which is presumed to be occupied by the Animike slates proper. This evidence consists in the existence of the red soft shale (1533) above the quartzyte (1534), This shale is apparently the equivalent of the red shale which have been penetrated in some deep wells in the central part of the state and found to overlie the quartzyte (the New Ulm quartzyte), and also perhaps of the red shale seen at Black River Falls, Wisconsin, on the south side of the "Tilden mound," to which it bears a strong resemblance, making thus the

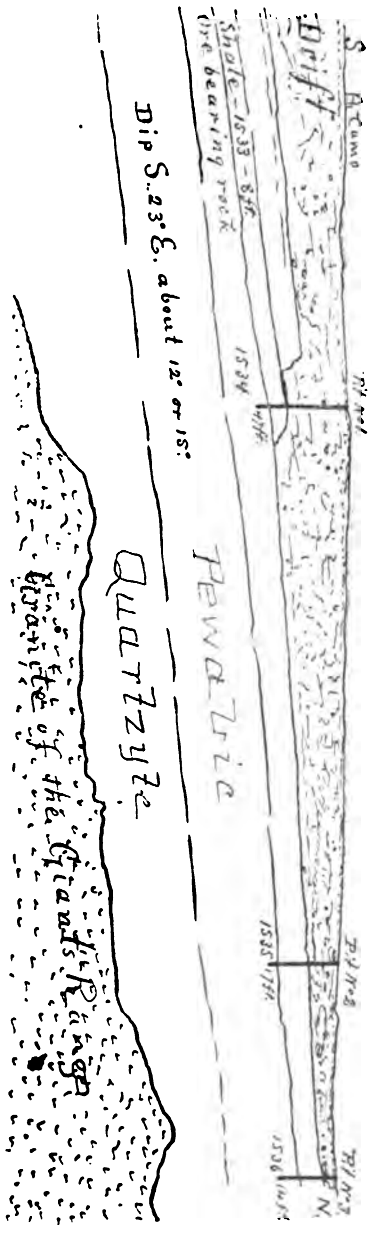


Fig. 2.

ore at Black River Falls the equivalent of that in the Animike (Huronian proper) in Minnesota, to which in its lithology and general character it has a close resemblance, as well as in its near proximity to a corresponding range of gneissic hills. It also confirms the opinion, elsewhere expressed by the writer, that the Gogebic ore is probably in the beds which, on the south shore, represent the Animike of the north shore, instead of the beds that contain the ore deposits at Vermilion lake. The structure here is represented by figure 2, showing an ideal section running north and south at Griffin's camp. The horizon is therefore very near that of the works of Mallmann, and of the mines in the Gogebic region.

There is yet one troublesome unexplained fact, which does not fall into place in accord with the idea that there is but one quartzyte and that it overlies the black slate unconformably, viz: The ore mines on the Gogebic range seem all to have an important granular gray quartzyte underlying them, and, according to all I know, a black slate lying to the north of them and probably stratigraphically above the ore beds, these black slates being supposed to be the Animike. If that quartzyte be the equivalent of the Pewabic quartzyte it certainly runs below the iron horizon, and the Animikie iron, the supposed equivalent of the Gogebic iron strata, should be sought for toward the south from the strike of the Pewabic quartzyte in Minnesota. As there are outcrops of slates and quartzytes, of the Animike series, along south from the strike of the Pewabic quartzyte it is also legitimate to infer in the absence of facts demonstrating to the contrary, that in Minnesota also the main mass of the Animikie, and hence also the horizon of the Gogebic ore, lies conformably above the Pewabic quartzyte, and may be found to the south of the strike of the quartzyte. In all the reports and inferences that have been published by the writer the Pewabic quartzyte has been made the parallel of the great quartzyte that overlies the Animikie unconformably, but it is possible that it runs below it conformably. Its age in either case is that of the great gabbro flood, with which it is interbedded at points further northeast.

Specimens from Griffin's camp, ne¼, sec. 22, 56-24, No. 1533, red shale, 8 feet; No. 1534, iron bearing rock, somewhat siliceous, ore-sheets broken and irregular, hematite; No. 1535, same as 1534, pit No. 2. but reached at 15 feet below the surface; No. 1536, same as 1534, 11 feet below the surface. No. 1537, slaty ore, rather ow grade, (47 p. c.) nw¼, nw¼, sec. 21, 56-24. Mr. Griffin says that in sec. 21 he knows that the rock 1537, lies to the south from the rock 1535 and 1536, in outcrop in the same section. He also says that at three or four miles south from his camp fragments of black slate are abundant in the drift, indicating black slate lying above the rock seen at his camp.

Where the road crosses the morainic belt (see the sketch-map, Fig. 1,) between towns XXIV and XXV, the hills are very conspicuous. It appears that the morainic belt coincides, in general, with the strike of the quartzyte, a fact which has been noticed before in Minnesota (and in Ohio, in case of a strike of the limestone as in Delaware county), and it is very likely that the existence of the latter had a powerful influence in determining the southward limit of the drift-laden ice.

That this range of iron ore is independent of and quite different from that at Vermilion lake, which is in the Keewatin schists, is shown, not only by the general geology and geography, and the difference in the manner of occurrence, as well as in the ores themselves, but by the fact that the line of strike of the Keewatin ore belt from Tower westward is found to cross the country about thirty miles further north. It has been discovered at several points, where it affords very encouraging outcrops, and samples of first-class magnetite have been exhibited by those who have visited the region. Mr. John Beckfelt, postmester at Grand

Rapids,[**] has manifested an intelligent interest in this more northern iron region, and from the samples in his possession the following were obtained: No. 1538, magnetic iron ore, sec. 23, 60, 23; No. 1539, rock associated with 1538. This is magnetic and siliceous, black, fine grained, apparently a magnetic jaspilyte.[*] This is described as standing vertical in the midst of vertical green schists. Charles Kearney, Grand Rapids, owns an iron location on sec. 27, 60-23, and — Fleck on sec. 23, 60-23; other owners are reported to be Lawrence Welsh, James Gill, Eli Signal, William Wynn, Al. Tory, J. H. Hennessy and — Knutson.

According to Mr. Griffin, there is an outcrop of "granite" at a point about ten miles south of Leech lake, the exact position of which he could not give. This indicates the strike of the Giant's range granite.

Gold in the Keewatin schists in northern Minnesota. It is well known that about twenty years ago, a gold excitement sprung up in Minnesota, centering on Vermilion lake.[†] Mr. H. H. Eames, the state geologist at that time, was largely instrumental in promoting the popular interest in that region, and in the reputed discovery of gold. The excitement subsided soon, and ever since then there has been very little said on the subject. But it appears now that there was some basis of fact underlying the excitement, and that possibly in the future the interest that subsided in 1866 may be partially revived. Several assays of auriferous quartz were published by Mr. Eames in his reports, some performed by J. R. Eckfelt, assayer of the U. S. mint at Philadelphia, others by professor E. Dent, New York, and by himself, which afforded gold amounting from twenty to thirty dollars per ton of the ore, with three or four dollars per ton of silver. This came from some of the workings about Vermilion lake.

In 1887, the writer visited the Marquette iron region in Michigan, and the Ropes gold mine northwest from Ishpeming.[||] He was at once impressed with the resemblance between the gold-bearing rocks seen all the way between Deer lake, near Ishpeming, and the Ropes mine and the rocks of the Keewatin, in northern Minnesota,[‡] and in all subsequent study, involving this question, he has placed the two localities provisionally in the same stratigraphic position. This parallelism at once recalled the early reports of finding gold at Vermilion lake, and aroused a suspicion that gold would be proved to exist in the quartz leads in the Keewatin, in Minnesota.

[**] Mr. Beckfelt also showed samples of lignite found "up the Mississippi river," say about Winnibigoshish lake. He also says it is reported to be found all about the shores of lake Winnibigoshish, in form of "float" pieces. He also states that he has seen pieces found "up the Prairie river."

[*] The occurrence of magnetic ore in the Keewatin, near Ely, as well as at Tower, is described in Bulletin No. 6.

[†] Compare the report of H. H. Eames on "The metalliferous region bordering on lake Superior," printed in 1866.

[||] Sixteenth annual report, pp. 48-49.

[‡] Seventeenth annual report, pp. 42-43.

In 1878, this region came again under examination by the state survey in a rapid reconnoissance, made by the writer, along the international boundary to Vermilion lake, and thence to the St. Louis river, and the principal "locations" were visited. The small specimens collected from the dump heaps were as large as the means of transportation would permit, and of course feebly illustrate what may have been the contents of the veins that were explored by the various owners in 1866. The samples are numbered 395–400, and 423, 428.*

Prof. A. H. Chester again examined these gold-mining locations, and states in his report that "Specimens were collected from many quartz veins, on some of which mines were formerly located, and all were carefully assayed. No true iron pyrites was found, but all was of that form known as pyrohotine or magnetic pyrites. Among the many samples of pyrites, from all parts of the country, assayed for gold at the laboratory of Hamilton college, not one containing magnetic pyrites has shown any gold, and so-called gold mines have been condemned at once when the character of the pyrites was recognized, subsequent assay always corroborating the opinion. It was, therefore, not a matter of surprise that these 'gold ores' did not contain any gold."‡

In 1886 Dr. A. Winchell examined the town in which is situated a prominent white quartz vein in which it was reported gold and silver had been found, and his collected samples at this point are numbered (of his series) 48-53.** He says: "Many quartz veins run through the whole formation. Rock 52 is a sample, containing hematitic stains, very much, indeed, as in some argentiferous[auriferous?] quartz. Other quartz veins are pervaded by pyrites in abundance, as shown in rock 53. In some cases a mass half the size of one's head is pure pyrites. The pyrites and quartz are sometimes seen to be intersected by minute, sinuous veins of a dark, lustrous iridescent mineral resembling peacock ore of copper. These are the glittering minerals which sustained, not without some reason, the hopes of the adventurers." At that time this spot was owned by a man, since deceased, named John Leienderker, who had sunk a shallow shaft in 1885.

---

*Ninth annual report, pp. 98-103.

‡ Eleventh annual report, p. 166.

** Fifteenth report, p. 32.

In 1888, in making some observations on the iron working of John Mallmann, about two miles south of the Giant's range, as reported above, the writer met Mr. Leienderker at Mallman's camp, and obtained from him a small piece of the quartz containing pyrites from his "gold mine" on Eagle Nest lake. Sec. 34, T. 62-14.

Some assays have since been made, viz:

Samples of pyritiferous quartz obtained by A. Winchell, from Leienderker's shaft, with the following result, assayed by Frank C. Smith, Ann Arbor, Mich.

A. Winchell's numbers 49 and 51, gave no trace of gold.

A. Winchell's number 53, gave one-twentieth of an ounce of gold per ton of 2,000 pounds, or $1.00 per ton.

Sample of pyritiferous quartz obtained by the writer from Mr. Leienderker; assayed by Prof. J. A. Dodge, Chem. Series, 212. Survey No. 1501. "Using one-half ounce of the ore, by fire assay, I find a trace of gold and no silver. The amount of gold is too small to be weighed from that quantity of ore; I should estimate it at not more than one-fortieth Troy ounce per ton."

All the samples from the various "locations" about Vermilion lake obtained by the writer in 1878, * assayed as one sample by Prof. C. F. Sidener, Chem. Series, 213, gave no gold nor silver.

The vein at Eagle Nest lake is said to be about 12 feet wide and to carry much pyrites throughout its width. The pyrite in the sample obtained from Mr. Leienderker is not magnetic in fine powder. It has a light brassy color and rectangular, apparently cuboidal, crystallization, which seem to indicate true pyrite. That which Prof. Chester examined was magnetic pyrite which is rarely if ever auriferous, and was at once condemned by him. There is a large amount of magnetic pyrite near the base of the Animike formation at the west end of Gunflint lake, associated with the magnetic ore of the Animike, which is of the same range and age as that investigated by Prof. Chester on the Mesabi range, and it is quite likely that the magnetic pyrite examined by him was obtained in that group of rocks. That has a different aspect and color from the pyrite at Eagle Nest lake, being a copper-steel gray, and also is much softer.

It appears from the foregoing considerations, and the facts that are known, that not only is there no *a priori* obstacle to the expectation of gold in the quartz leads of the Keewatin, but that there is some positive basis of fact to show that it exists there in quantity sufficient, in some †cases, to make a valuable low grade ore that could be profitably mined by the same methods as those employed in the Black Hills, and at the Ropes mine in Michigan.

---

* Ninth annual report, pp. 98-103.

THE CRYSTALLINE ROCKS OF THE MINNESOTA VALLEY.

In June 1888 some observations were made about Redwood Falls. At Frazer's quarry, in Honner, (N. Redwood P. O.) which is on the south side of the Minnesota, but on the northwest side of the Redwood, in the bottom lands of the Minnesota river, can be seen gneiss, some of which is prevailingly red on weathered exposures, but on quarrying deeply—and some without being quarried—is gray. This rock is a gneiss, through and through, having a "rift" which is strongly marked, and generally evident in difference of colors and in micaceous belts, the alternations being black, quartzose, feldspathic, reddish, &c. There are some places that show up as a massive, gray gneiss, without much banding, but the whole rock is generally quite banded. Across these forms run granulyte veins, and coincident with the gneissic bands are other orthoclastic belts, some of them plainly fading out into the gray gneiss, and some being distinctly separate for many feet. These are either of chemical deposition entirely, (as when filling transverse fissures) or are produced by slow chemical metamorphism from the original sediments. In two instances one of these veins, about ¾ in. wide, running transverse to the grain of the gneiss, split in the center of the vein, and one-half of it adhered to one block, and the other to the other block, when forced by the operations of the mine. This splitting ran about six feet, and showed, when cleared off, a surface 16 in. by 6 ft., and at a distance I took it at first for a vein 16 in. wide because viewed from that direction. This vein matter was coarse red granulyte. Other similar veins when viewed on the broken edge showed a distinct *central plane of union* between the growing accumulations on the opposite side of the original fissure, just as in common mineral veins, thus: Fig. 3. Such a plane would be a plane of weakness, along which in quarrying, the rock would be likely to part.

---

†Capt. Gibbons, in test-pitting for iron in 63-11, is reported to have found a nugget of gold valued at about four dollars, and Mr. J. G. Emery affirms that in the quartz veins in the greenstone on the southern slope of the Twin peaks south of Ogishkemuncie lake he has very frequently obtained gold. It might also here be recorded that according Mr. Emery, who showed me a sample, a finely granular graphite occurs on lot 9, se ¼ sec. 18, 64-6, (east of Frazer lake). He describes it as surrounded and overlain by gabbro. At a mile further west, and a little north, it shows on the surface in a vein ten feet wide; and pieces as large as a half bushel lie about, as if thrown out by the frost. It is also found on the portage trail (a little north of the trail) from the east end of Frazer lake to the lake next toward the southeast. Considerable iron ore is reported by him in the greenstone, in the north parts of secs. 2 and 3, 64-6, i. e, in the region of the Twin mountains.

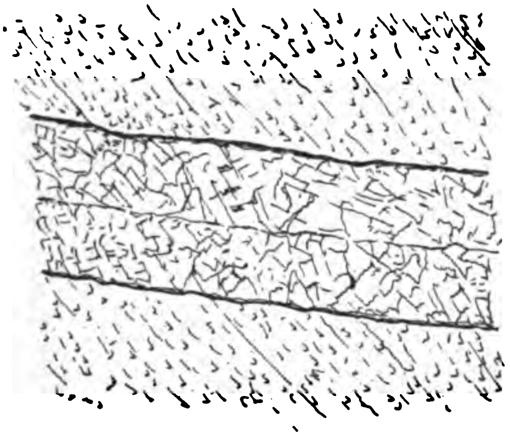


Fig. 3. Layered vein of Granulyte.

At Morton, a few miles below Redwood Falls, situated in the valley of the Minnesota river, Saulspaugh has recently opened extensive quarries in the "granite." Here the rock is mainly a gray contorted gneiss, but it has, in all the usual forms, much reddish feldspar supposed to be othoclase. Veins of granulyte cut the gneissic structure. One was 14 inches wide and was banded in the same manner as illustrated by fig. 3 above, except that its course was nearly perpendicular to the gneissic rift, and it showed, further, a banded alternation of quartz and feldspar, as illustrated by fig. 4 sketched on the spot.

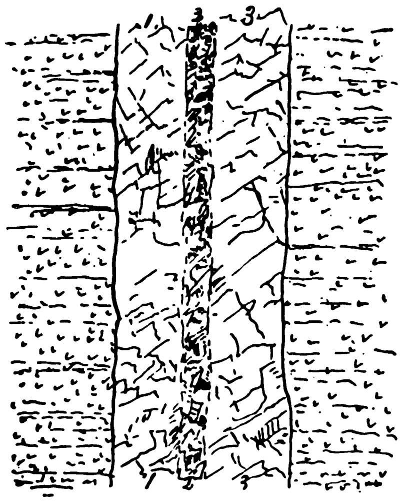


Fig. 4. Vein of Banded Granulyte and Amethystine Quartz.

Explanation of Fig. 4.

No. 1. Coarse orthoclase, with little quartz.

No. 2. Coarse crystalsof quartz, somewhat amethystine.

No. 3. Same as No. 1.

This shows a true vein structure, and a chemical origin for the "dyke." The figure shows the planes separating the quartz from the orthoclaserather more abrupt and straight than they are in nature. Along the line of contact some of the orthoclase crystals penetrate within the quartz zone, and there are a few quartz crystals disseminated through the orthoclase. But, as a whole, the central band of amethystine quartz is distinct and constant.

Another remarkable feature in the Morton quarries, where there has been more work done than in any other granite quarries in the state, and from which they have sent rock for street curbing to Duluth, is the beautiful contortion of the gneissic structure, which on being broken, and especially when cut-hammered, makes a striping resembling that seen on some fancy marbles.

And yet another feature, which allies this belt with the transition series at the northwest end of Vermilion lake, is the irregular mixing of the "mica schist," or "black rock," with the gneissic lighter-colored rock. These so-called mica schists appear as isolated masses, one as large as ten feet across, but usually only a few inches in diameter, like boulders in the midst of the gneiss. In one conspicuous instance, seen on a freshly cut block of gneiss, the laminations of the gneiss were seen to shape themselves about the black mass. In many other instances the black patches are changed in shape, apparently by some shearing pressure incident to the whole formation. They are elongated and bent and strung out like hooks and lenticular bands, in conformity with the direction of the general trends of the gneissic contortions.

While these black patches appear (now) to be largely micaceous and of the same nature as the micaceous element in the gneiss, yet there is noticeable a difference. They seem to be of changed hornblende or hornblendic rock (1519.) The "black rock" in one limited space was seen to comprise at least half of the whole, and it seemed to be the same ingredient as the black element in the gneiss—at least so far as its distribution and relations could be seen to show anything of its origin. This "black rock" should not be confounded with another "black rock" which in the form of a conspicuous more recent dyke cuts across the hill composed of gneiss.

The general similarity of this quarry to the mixed condition of the mica schist and syenite in the northwest part of Vermilion lake, where the Vermilion series fades out into the gneiss proper, of the Laurentian, is forcibly impressed on the mind of any one who is familiar with the latter. The transition in the Minnesota valley, however, seems to occupy a wide belt, as it extends at least from Redwood to Morton—and indeed to occupy nearly the whole valley.

In town 111-38 (unorganized), of Redwood county, sec. 12, is a glaciated granite knob, the striæ running S. about 45° E. This is a dome of gray contorted gneiss, rising about twelve feet. Its visible extent is about 200 feet, and 90 feet across. Its elongation is NW. and SE. It is a good rock for heavy quarrying, as it is not much jointed. It is heavily bedded by a series of overlying layers that dip gently toward the south, so that the steep side of the knob is on the north slope. The country round about it is wild, unoccupied prairie, smoothly rolling.

This rock shows no red feldspar, in that respect being somewhat more like the Honner quarry than the gneiss at Morton. The top is somewhat below the average level of the country, and has been uncovered by the removal, by some means, of the drift cover. The field can be plowed right up to the rock on all sides.—Sample 1520.

In making this trip a new sort of boulder was seen in many places—a white granular quartzyte, some of them two feet across. They show a plain sedimentary structure, and are rather fine-grained. They are hauled with other boulders into piles from the fields. They look like the usual "Winnipeg" limestone, of which not a piece was observed on the trip, although they do occur about the mouth of Crow creek.

Re-examination of Lignitic beds about Redwood Falls. In company with Mr. Park Worden, Capt. Dunnington and Mr. Terrill, of Redwood Falls, a number of workings in lignite beds in the vicinity were examined, particularly in the region of the valley of Crow creek. One of these was the very spot that I visited 15 years ago, now caved in, and nearly lost to sight. Another was visited with Mr. Peabody at the identical spot where Grant and Brousseau tried to get coal about 20 years before. None of these reveal anything new, nor give any reason to vary from the judgment and descriptions published in the second annual report, respecting their geological age and prospective economic value.

At Mr. Farrington's, on the bluff of the Minnesota near Crow creek, the lignite lies on the decayed gneiss, or on a somewhat stratified and re-arranged condition of it, due to the Cretaceous ocean. There is no conglomerate at the bottom—only this kaolinic material.

III.

RECORD OF SOME FIELD OBSERVATIONS MADE IN 1889.

Duluth. On the "Weller road," about a mile and a half from lake Superior (at Duluth) and about two miles, by the road, from the business part of the city, is the spot that has been referred to *before as showing considerable amounts of red rock in the hills.

---

*Survey samples of N. H. Winchell, Nos. 1B. 46.

Compare also Proceedings of the American Association for the Advancement of Science. 1881. Cincinnati meeting, *Typical thin sections of the Cupriferous rocks in Minn*

There is not so much of it as I had thought. It is very certainly the same rock, and has the same relation to the gabbro as that seen at Duluth and mingled with the gabbro at Rice's point. It is here in a scattered blotch, and in thin veins, in a fine porphyritic, gabbroloid rock—which last is like much seen in the city and environs of Duluth, but not so perfectly and coarsely crystalline as the Rice point rock. While the gabbro is quite different from the typical gabbro at Rice's point, it is essentially the same rock and of about the same age. Indeed it is almost possible to trace it continuously from one place to the other along the hill range that connects the two places. No. 1540 shows the gray porphyritic gabbro with a fine magma. No. 1541 shows contact of the red rock on the gray rock, 1540. No. 1542 is the crystalline red rock, with some light green spots. No. 1543 is chalcedonic quartz from this gabbro, as described below.

A very interesting observation is made in connection with this modified gabbro. On the weathered surface, where it also presents other irregularities of structure, resembling coarse amygdaloid, are seen white spots of silica. These spots are sometimes vitreous and glistening, as if of chemically deposited quartz, and in some central cavities quartz crystals form a drusy coating. But in other places this pure vitreous white quartz becomes granular, there being a gradual passage from one structure to the other, the granular increasing in distinctness and ease of disintegration toward a weathered angle, or toward the surface. Very rarely, small, subtranslucent areas as large as a wheat grain, or larger, can be seen, on the disintegration of the vitreous portions, which do not disintegrate, resembling amorphous or chalcedonic silica. The disintegrated granular portions, however, are not uniformly fine, and, in general, those portions are all coarser than the fine granular silica of the so-called chalcedonic silica of the iron mines. This observation shows:—*That the granular structure seen in silica, does not prove necessarily that the silica was of sedimentary or clastic origin*, since this is plainly the result of long weathering of chemical selica in these exposed cliffs.

These quartz masses do not show plainly a banded agate-like structure like the agates seen at Agate bay, or Gooseberry river, but in some of them there is a narrow band of harder, somewhat reddish, siliceous rock that surrounds them and forms an enclosing ridge that rises above the general surface. They vary in size from a pea to eight inches long, and while not very sharply angular, are not of the shapes of usual amygdules. Some of them have little cavities of irregular shapes in which small quartz crystals are seen projecting, and in others the white vitreous quartz is replaced, in marginal patches, or even in larger table-like protrusions, by a milky, opaque quartz, as mentioned above. Taken altogether it seems very likely that these quartz modules are indigenous in this gabbro-like rock, and are not of the nature of foreign or transported masses, but have originated in the gabbro by secretion, in a manner similar to the chalcedonic agates in the trap at the mouth of Gooseberry river (519).

At the Iron Mines at Tower. The designations of the various "mines" have been changed since the ownership changed. They are now known by number, viz:

No. 1 is what was known, and designated in our former reports as the Stuntz mine. It is the most easterly of those on the southern slope of the "north range."

No. 2 is what was formerly known as East Stone mine.
No. 3 is what was formerly known as Stone mine.
No. 4 is what was formerly known as Stone mine.
No. 5 is what was formerly known as East Ely mine.
No. 6 is what was formerly known as West Ely mine.
No. 7 is a pit on the former Tower mine.
No. 8 is what was formerly known as the East Tower mine.
No. 9 is what was formerly known as the West Tower mine.
No. 10 is what was formerly known as the Lee mine.
No. 11 is what was formerly known as the East Lee mine.
No. 12 is what was formerly included in the Breitung mine.
No. 13 is what was formerly included in the West Breitung mine.

Under the direction of Mr. H. A. Wilcox a systematic probing of the region has been carried on by diamond drill. This has resulted in the discovery of the existence of ore in some places not known before, and particularly near Tower in the "south ridge" or Lee mine. Some of the particulars of this drilling have been supplied to the survey. Indeed, through the courtesy of Mr. Geo. C. Stone, and of Supt. Bacon, every part of the mine, and all the records whether of drilling, assaying, mapping, shipping and grading, pertaining to the operation of the company, were thrown open to the writer for the use that might be wished for the purposes of the survey. Much assistance was afforded in making this re-examination, by the co-operation of the officers and the mining captains of the Minnesota Iron Company, and especially by the records of the drilling and some chemical analyses, the former by Mr. H. A. Wilcox and the latter by — Waters. Most of this detailed information is to be found in the special report on the iron ores of the state—

Bulletin No. 6, accompanying this report, but published separately. Subsequently the same courtesy was extended to the survey by the superintendent and other officers of the mines at Ely.

The purpose of this more detailed re-survey was to arrive, as nearly as might be, at a final conclusion, based on facts observed in the field, touching the question of the origin of the iron ore; and while that was a primary purpose, it was intended also to obtain more details of the actual manner of occurrence of the ores, the operation of the mines, and all the statistics that would be needed in making a full presentation of the iron ores in published form.

These observations were made in company with, and by the assistance of Mr. Horace V. Winchell who had previously examined many iron localities in the state, and had been exclusively at work on the iron deposits for about a year, and who was familiar with all the theories that had been proposed, and the obstacles that they met with. We subsequently published in *The American Geologist,*[*] a summary and preliminary statement of the probable result of the investigation, so far as it related to the origin of the ore itself, and the same view is presented again, more fully, with many facts that sustain it, in another part of this report.

At this place but little more will be given than the connected thread of successive field observation, with references to the illustrative rock samples, and some of the steps in the argument.

At the Lee mine, rock sample 1546. Here we collected some of the quartz crystals lining vugs in the dense hematite. These have not the clouded "chalcedonic" appearance of crystals formed rapidly, or of rapid chemical accumulation without crystalization, such as seen in the quartz in the jaspilyte. This kind of quartz in the ores of the district has frequently been described in the reports, and it has been supposed to have had a later origin than the jaspilitic quartz.

In the dump at the Lee mine (No. 10 as above,) is seen a reddish, earthy-looking jaspilyte, beautifully streaked as with sedimentary banding—No. 1547. It contains much pyrites, which is in bands and streaks coincident with the banding, this being apparently the form taken by the ore when accumulated under circumstances that gave the jaspilyte this earthy character. While this pyrite is disseminated minutely through the whole of this, yet in larger quantity it frequents certain bands. It is noticed that these bands cease abruptly along one side, when viewed on the broken edge of the sedimentation, as if the conditions allowing its formation were wholly and suddenly changed in that direction. But on the other margin the pyritiferous bands fade out gradually in the midst of the other rock. This is the first instance in which any such variation, indicating an upper and a lower side to the jaspilyte in the process of formation, has been observed. It is probable that the line along which the abrupt change is introduced was the lower side of the pyrite band, and if the position of this impure jaspilyte within the mine, with respect to the strike of the ore mass, could be ascertained, it would furnish a key to the stratigraphic order of super-position of strata of the region–a desideratum which has not yet been supplied by actual observation, though it has been hypothetically deduced from a general view of the whole region. The principal pyritic streaks are about a quarter of an inch apart, but there are intermediate variations that also produce streaks, and on one side of the specimen collected the principal streaks are about three quarters of an inch apart, and somewhat undulating.

---

[*] American Geologist, vol. iv. p. 291. *On a possible chemical origin of the iron ore of th Keewatin in Minnesota.*

In other pieces this impure streaked jaspilyte appears as a pyritiferous impure hematite, and in others, still, the pyritiferous character is generally disseminated in the breccia of hematite and earthy jaspilyte. In larger cubes the pyrites is seen in a sort of soft greenstone.

1548. Breccia, a somewhat stratiform mass of fine pieces of red jasper, hematite, jaspilyte, quartz.

1549. Crystals that seem to be chalcopyrite, colored sometimes blue like erubescite (?) or bornite, Lee mine.

[On further examination these blue crystalline grains seem to be hematite tarnished.]

1550. Finely banded, whitish jaspilyte, part of a breccia, Lee mine.

1551. Hard hematite, with conspicuous included crystalline masses that appear to be chalcopyrite.

Going in the pit of the Lee mine, which is now 100 feet in depth, under the direction of the foreman (because we inquired as to the place of rock No. 1547 in the mine), we find the succession across the Lee mine to be as follows:

In fig. 5, which is an outline plan of No. 10, formerly known as the Lee mine, the star (*) indicates where the bedded rock, No. 1547, was found. Next north of it is breccia, with green stone material, with considerable pyrite and with the well-known white kaolinic, white substance. In the kaolinic material are sericitic, but rather hard and coarse-grained pebbles. There is an abrupt transition from fine, hard hematite to the rock 1547, but the contact, which can, with some difficulty, be traced out on the face of the wall, is tortuous and oblique. In the kaolinic material are also rounded pebbles of No. 1547. The general order of succession, across the mine, is thus, from north to south.

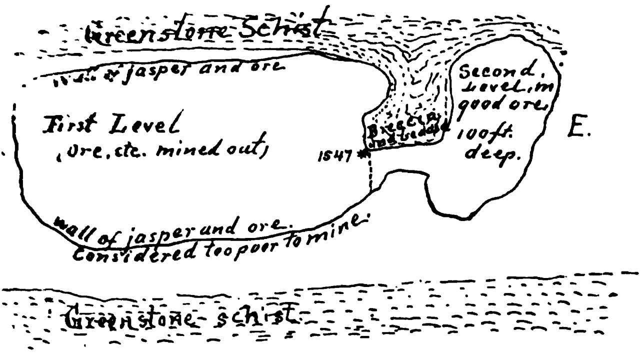


Fig. 5. Outline plan of the Lee mine.

1. Greenstone of the country, a chloritic schist, north side of the mine.
2. Breccia of greenstone, impure jaspilyte (rock 1547) and iron ore, with much pyrite.
3. Red, impure, sedimentary banded jaspilyte, somewhat resembling, in some places, a red shale, though it is always too hard and too heavy to be called shale. It is different from the well-known jaspilyte, as it shows no distinct chalcedonic silica, and only occasionally any distinct lines of hematite. It is not an important deposit, as to its amount, but apparently quite so as to its nature and origin, and its possible relation to the pure jaspilyte.
4. Fine, hard hematite, pure.
5. Main mass of ore; at its narrowest place about five feet wide, at the present face of the slope.
6. Jaspilyte, too poor to mine.
7. Greenstone schist, on the south side of the mine.

It seems as if the succession of formation progressed from the south to the north (or from No. 7 to No. 1), the impure jasper, No. 3 (or red shale) being formed by wash from No. 4, but rendered soft and impure by influx of materials from No. 7, or some other adjacent greenstone, and accumulated only in favorable nooks, followed by another greenstone (or schist), the latter serving, not only to break up and embrace in form of a breccia all the foregoing (Nos. 7 to 3), some of the inclusions being from the impure jaspilyte, some from the iron ore, and some from the jasper further south, but to contravene all the forces, whatever they were, that deposited the jaspilyte, and to substitute its own products entirely, with little or no modification, for the hematite and silica that had been deposited immediately before. If this schist (No. 1) were an undoubted, massive, homogeneous, non-clastic rock, it would be necessary to infer that the jaspilyte had been covered by a diabase overflow, and that in the bottom of the lava the materials of all the former strata had been involved in a brecciated condition. The occurrence of this breccia on the north side of the main jaspilyte mass, however, is not conclusive evidence of the later date of the origin of the northern side of the Lee mine, since there are jaspilyte masses in the green schist further north still, and some of them, when they were entire and continuous in one mass, may have supplied the material for the breccia, allowing the order of formation to have been from north to south.

Not far from Lee mine, by the old roadside leading to the Breitung mine and to the "location," on the top of the main hill, a large boulder was found of the Stuntz conglomerate, and its examination afforded some interesting facts.

1. This boulder contains pebbles of chalcedonic quartz (1552), some of them being several inches across.

2. It contains pebbles of gray, quartzose felsyte (1553 and 1554).

3. In these felsyte pebbles, which themselves are older than the boulder in which they are embraced, are rounded vitreous quartz pebbles which do not indicate any granular structure like the so-called chalcedonic silica.

4. Some of the pebbles of 1553, represented also by 1556, seem to exhibit an imperfect porphyritic structure, approaching that of "porphyrel" at Kekekebic lake, which they also resemble in nearly all other respects. This may point to some relationship between the Keewatin schists represented by the Stuntz conglomerate, and the porphyrel. The rocks, however, need a closer comparison.

The important result of this observation, however, is in the bearing it has on the nature of the granular structure of the jaspilitic silica. It has been presumed by some that the jaspilitic silica is granulated because of incipient decay, in the manner that the geodic silica in the gabbro near Duluth becomes granular. Not to mention here the evident difference between the granulation that is due to decay and that which is seen in the chalcedonic silica of the iron mines, it is sufficient to call attention to the perfectly intact vitreous condition of the quartz *pebbles within the pebbles* in this boulder, even when by fracture they have been brought to the surface of the boulder, and the perfectly characteristic chalcedonic granulation seen in the younger pebble of jaspilitic silica, No.

1552 above. That which is non-granular in this boulder is necessarily older, and has suffered more revolution of physical exposure, than that which is granular, for it is embraced within a smaller pebble, whereas the granular-silica pebbles are not so embraced. The granular silica pebbles are of the age (so far as respects the formation of this boulder) of the gray quartzose felsyte which incloses the non-granular silica pebbles. The inference is inevitable that it cannot be exposure and incipient decay which causes the granular condition of the jaspilitic silica.

We visited again the place that has been so many times referred to south of the Stone mine (pits Nos. 2 and 3) where, at the railroad cut, there is such a curious mingling of the green schist of the region with jaspilyte. I visited this cut with M. E. Wadsworth in 1886, to call his attention to the sedimentary interbedding of the schist and jaspilyte. There is a thin-leaved interstratification, and the jaspilyte is genuine, as such, not in "compound grains" as I had surmised. Cutting all this chalcedonic quartz are distinctly different veins of glassy quartz, of chemical origin, which has to be kept separate from the jaspilyte, some of them being six inches wide, and others not more than one-fourth of an inch—also geodic masses of the same.

Not only is the chalcedonic silica here interbedded, in lenticular sheets of the extent of one to three feet, (but frequently of less extent) but also there are small pieces disseminated through the schist, from the size of a pin-head to that of a man's fist, and also large masses having a red and purple color, placed somewhat irregularly in the schist.

There is also a siliceous base in the schist, which has this same chalcedonic grain, and some layers, (lenticular still) of a hard green rock, apparently more charged with this same silica.

As to this manner of occurrence of jaspilyte, I cannot make it consistent with any eruptive hypothesis—nor yet with sedimentary. The green schist is not here clearly of sedimentary structure, though there are variations in it to a more firm and siliceous character, that may be attributed to sedimentary accumulation. It appears to be best explained by supposing a combination of eruptive and aqueous agencies.

South of the Breitung opening, near the west end of the so-called "north ridge," runs a narrow streak of ore, about east and west, and since I saw it last it has been worked some. Westwardly it suddenly ceases, and a swampy patch supervenes, so far as can be

g from
ontain,
s layer
breccia
e small
itreous
n many
cedonic
y mass-
n chal-
no such
On the
granu-
rounded
silica in
eady de-
the Lee
bly jas-
tributed
ng an ir-
center of
e, and is

of the
hard rib-
l bands.
siliceous
with the
red and
r of the
em pinch
. One of
few inches
enclosed it
te surface,
that are ex-
, and transi-
green schist
bly modified
a liberal per-
it not for the
ly

of the ore itself there is considerable pyrites, and on the southern surface of the ore-streak can be seen some original jaspilitic silica, where the hematite is hard. There is in this ore-belt, besides, a considerable amount of limonite, some of it in botryoidal surfaces on quartz crystals, and on hematite (1564). The limonite sometimes is further covered with a thin blue coat, and in some cases, especially in the vicinity of pyrite, there is a surface of coxcomb crystals, like hematite, covered with black, which last possibly is manganese.

A little to the south of this opening is a shaft for hoisting from this pit. It seems to have encountered flinty, gray to dark gray, jaspilyte (1565) judging from a large number of fresh, large pieces that lie near in the dump, (=866 B). Compare 1277.

The principal Breitung opening is very irregular, the direction of strike of the main ore mass winding about in the green schist from east to west so as to run nearly north and south, and abruptly ceasing, or beginning where not expected. Three things are noticeable in conjunction with the ore.

1st. It is heavily jointed, about horizontally, but this jointed part is better ore, and lies below a less jointed mass of jaspilyte, the line between them being characterized by a rotted belt (1566), running diagonally across the face of the wall and descending toward the west. This belt where most rotted is a breccia, so that it is easily dug out even by the hand, and the part that disappears by rotting consists of angular jaspilyte masses. Several other beds of similar soft and rotted material are seen in the ore, sloping toward the west, some of them being lenticular. The occasion of this rotting is the existence of the joint, into which water enters at the top of the ridge where it comes to the surface. The joint cuts everything, rigidly, whether breccia or not, and the breccia is most disintegrated by the moisture and frost. This is evident because, while the rotted belt in the main follows the sloping joint, the rotted belt widens out when it approaches and cuts a breccia layer or mass, in the main rock, and in other places the beds of jaspilyte are preserved entire or mainly so (when not breccia) across the rotted layer.

2nd. The surface of the ore abuts immediately on the greenstone, and the two surfaces are mutually slickensided, the greenstone, in one instance at least, having a fine, curved, semi-basaltic structure which at the junction is nearly perpendicular to the surface of contact. But in other cases the schist is red and hard along the contact for some distance, say for twelve or sixteen inches, and is closely cross jointed and broken, rendering it fissile in small angular lumps.

3rd. In the remaining ridge, which separate the Breitung from the Tower, the firm jaspilyte of which it consists is seen to contain, in several places, and in one place in a somewhat continuous layer traceable, with some interruptions, twenty or more feet, a breccia and conglomerate, one inch to four inches wide, in which are small rounded, or sub-rounded, at least water worn, pebbles of vitreous quartz (1567). There are, on both sides of this band, and in many places over this immediate vicinity, spots of breccia of chalcedonic silica, cemènted by smaller breccia and pebbles, as well as by massive chalcedonic silica, all of which consist of the well known chalcedonic silica. But in the above vitreous silica there is no such fine grain as that which characterizes the jaspilitic silica. On the hypothesis of decay and disintegration, as the cause of the granular condition, why is not this condition seen also in these rounded vitreous grains which must be older than the chalcedonic silica in which they are embraced? This observation, like that already detailed on the pebbles of a large boulder seen not far from the Lee mine, negatives all resort to such hypothesis. In this pebbly jaspilyte the vitreous quartz grains, although obvious, are distributed rather sparsely, and the whole space they occupy, forming an irregular and interrupted vanishing belt, or layer, near the center of the main mass, is not more than three or four inches wide, and is not a noticeable band.

North of the Tower mine (No. 8), on the north slope of the north ridge, is a conspicuous shoulder-like protrusion of hard ribbon-jasper, with characteristic undulating and contorted bands. This jasper has five or six thin layers of green schist, or siliceous green schist, running through it, which were cotemporary with the formation of the jasper, since they are flexed with the red and white bands. These layers enter on the eastern border of the exposure and continue zigzag across it, but some of them pinch out or fade out before they reach the eastern border. One of them, after such disappearance, rises again faintly a few inches further west between the same colored bands that enclosed it further east. Figure 7 was sketched from this jaspilyte surface, with the design to indicate the forms and alternations that are exhibited, but no drawing can show all the contortions, and transitions, and alternations. The shaded part is one of the green schist bands. On close inspection it is found to be considerably modified from the typical green schist of the country, having a liberal percentage of silica—indeed it is so siliceous that were it not for the contrast it presents with the smooth, hard jasper it would hardly be called green schist. Other belts of it, however, are less firm, and fade gradually into a softer (yet comparatively siliceous) light-green schist which cannot be mistaken for anything else than a part of the same rock as the green schist of the country. In case of all these green schist belts, though more siliceous than the average green schist of the country, they have disintegrated and been removed by the action of frost and vegetation, so that along their course across the jaspilyte knob, are little tortuous grooves due to their more rapid decay. A photograph was made of this jaspilyte surface, for which see bulletin No. 6.

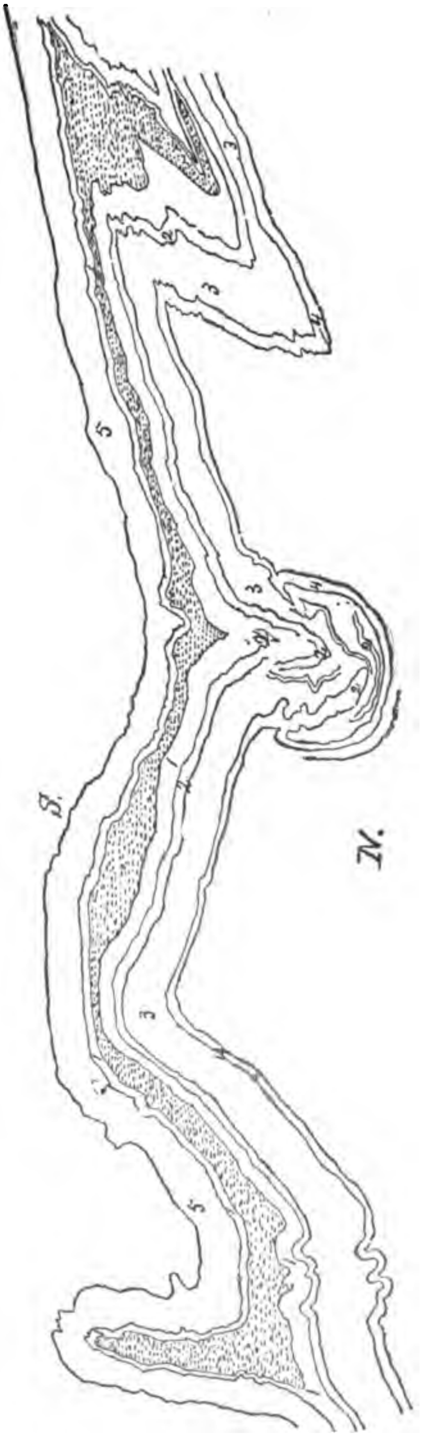


Fig. No. 7.—Green schist interbedded and contorted with the jasper ribbons.

In Fig. 7 the hooked expansion and sudden termination of the green schist band are in connection with, and a part of a general contortion in the jaspilyte which bends in the same direction, *i. e.* some of the thin layers do. The lamina of green schist, in an attenuated condition runs from the end of the hook some further and squeezes out gradually, and is lost, the jaspilyte walls coming together, so far as the appearance shows on the glaciated surface. Beyond the keel of the hook, however, in the general course of direction of the band, the green schist band appears again, and continues as far as the uncovered condition of the surface will allow of its being traced. Here the contortion is in the form of a swelling and lifting toward the north. The beds next south run along without showing any sympathy with this irregularity. There is also a similar protrusion and contortion seen on the north side near the center of the sketch. On the south side here also the jasper ribbons are not disturbed. These contorted protrusions toward the north must have formed before the formation of the succeeding jasper bands in that direction, because, not only do they not participate in the contortion, but easily pass by the protrusions with gentle swells and flexures that are independent of the close crumpling.

The shaded part (Fig. 7) is a belt of green schist. No. 1. at the left is a thin scale of brown jasper. Toward the right further it is gradually replaced by a thin scale, and further still to the right by a narrow ribbon, of hematite. In this brown jasper are lenticules of crimson jasper, presenting a maculated handsome surface. It also shows the fine lamination one thirty-second part of an inch wide which has before been mentioned as a characteristic of the jaspilyte ribbons. It also embraces thin sheets of hematite, and it is cut and cemented by transverse veins of crystalline vitreous silica. No. 2 is mainly hematite, but it has threads (really sections of sheets) of brown jasper; and at the central swell it is rendered impure, being broken, spread, separated by brown jasper sheets, and occupies, with the jasper associated with it, the whole of the swell. No. 3 is a broad band of brown jasper, that also shows the crimson jasper already mentioned. No. 4 embraces a group of hematite sheets interleaved with jasper, too thin and too close to be separately traced. No. 5 is a band of hematite which, at the east end of the sketch is seen to be flexed southward so as to embrace and to coincide with the pot-hook direction of the green schist, but toward the west runs independently of the sharp north-side hook at the west end of the sketch.

The inevitable inferences from a study of this rock surface are: (1) that the two substances, the green schist and the siliceous jaspilyte and the hematite were the product of practically identical forces acting on different objects; (2) that after the formation of some of the narrow bands they were disrupted and contorted before the formation of the next succeeding bands; (3) that the southern side was the lower, and hence the older side, and that the growth was from the south to the north (as the beds now stand); and (4) that there was usually a complete cessation of the deposit of the siliceous jaspilyte when the materials of the green schist were accumulating, and *vice versa*, but that occasionally, as illustrated in these rather hard bands of green schist, the two substances were deposited simultaneously.

Any theory that will satisfactorily account for the origin of the Keewatin iron ores, must allow for these inferences from the physical structure at the same time that it plausibly accounts for the origination of the elements of which the jaspilyte and the green schist consist.

The fact that there was some force concerned that could fracture the last-laid-down layer without disturbing the deeper ones, and that it was remittent, so that succeeding layers were normally formed and were not fractured is demonstrated also by a sketch made here showing an interrupted layer of brown jasper, the separated parts being surrounded by hematite and embraced in a continuous schist of it, one of the integral bands of the jaspilyte, but themselves also seamed by crystalline silica at other points. See bulletin No. 6.

I am impressed with the indications that this silica is arranged by sedimentation. What was its origin?—probably chemically precipitated; perhaps also that of the St. Peter sandstone, although they are very different in respect to size of grain and in age. The eruptions of basic rock that characterized the Keewatin must have made such changes in the chemical conditions of the oceanic water that silica and hematite were thrown down. Can that be shown? Then came, if not the minute crumpling, at least the general tilting which has brought the beds to verticality.

It is well known that the first attempt to extract ore from these hills was made by George R. Stuntz and John Mallmann. Mr. Mallmann happened to be at Tower at the time this examination was being made, and he kindly pointed out the spot where this working was done, and we made a photograph of the same. It is near the Lee mine, on the south side of the "south ridge," not far west of the east opening (No. 11). By the blast one large lenticular mass weighing three or four tons was rent from the south side of the jasper bluff. The photo is intended to show this. In the hole excavated by the men and by the blast bushes have now grown up, but the course of the drill is still visible on the upper side of the dislodged mass. The photograph is reproduced in Bulletin No. 6.

In the highest of the tunnels of the Tower mine, which discharges southward, and also the most westerly, and at the southern end, is a north and south rock-cut which seems to trans-sect at a more western point, the rock to which I have so often referred at the railroad cutting immediately south of the Stone mine, about half a mile further east. The mixed and generally interleaved condition of the green schist and the jaspilyte is the same, but at this place, as the cut is across the structure more can be seen of the relations of the two rocks, viz.:

1. The jaspilyte is contained in the schist in lenticular masses, and in thin interleaved vanishing sheets that have their sharp edges upward and downward. This is most manifest, in innumerable instances here within the horizontal space of thirty feet.

2. The jaspilyte is contained in similar masses that terminate east and west in the schist.

3. In the space of 22 feet, north and south on the face of this cut, I count 36 jaspilyte layers, varying in thickness from ½ inch to 24 inches, all of them having at least 6 inches extent up and down, the rest of the rock being green schist, or jaspilitic red schist (or "shale" similar to rock 1547). Besides these there are some indefinite graywacken layers containing rounded pieces of jaspilyte as pebbles.

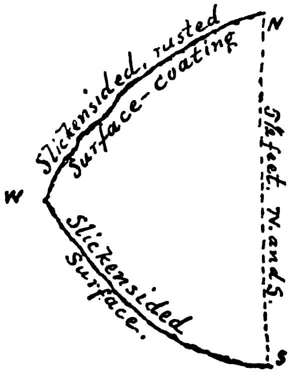


Fig. 8.
Western termination of a jaspilyte lenticule.

4. On the east side of the cut is seen the manner of termination of one of the larger lenticules of jaspilyte, in the midst of the schist, the exposed terminal end appearing unbroken near the track, though broken off at the top by the work of making the cutting. The shape of this western termination is represented by figure 8, which shows a section across the lenticule north and south.

5. Within two inches of this large mass, sketched above, was a smaller, apparently concretionary mass of jaspilyte, about 18 inches in its greater (perpendicular) diameter, appearing on the face of the cut to be entirely surrounded by the green schist and separate from the larger lenticule. Desiring to know whether it was connected with the foregoing large mass, I had a crow-bar brought, and, on making some excavation about it, the smaller egg-shaped lenticule was dislodged entire and fell to the ground. It left a continuous concave socket, the exact imprint of itself, and was coated and smoothed over its whole exterior in the same manner as the larger one, and was wholly independent and

separate from it. It is numbered 1568. It is sharper, in cross section, at the upper end than at the lower, and while about 18 inches in perpendicular diameter it is four and one-half inches thick (n. and s.) and eight inches wide (*i. e.*, east and west). Several small parts, broken from the upper end before it was dislodged, are also given this number. This shows that the egg consists essentially of hard chalcedonic silica, with a little hematite.

6. Within the tunnel, toward the north further, the green schist contains graywacken bands. In these are small pebbles of chalcedonic silica, but, in 1569, can be seen three ($\frac{1}{4}$ in. thick) veins of chalcedonic silica crossing the structure of the green rock at oblique and varying angles. This was taken from the roof of the tunnel, about 15 feet from the southern entrance.

7. In No. 1568 the principal color-bands run across the face of the section, and are not wholly concentric. There is a series of accretionary bands, surrounding these and inclosing them with an outer rusty coating, which gives color to the supposition that the egg is wholly concretionary. These outside bands fade off into the green schist structurally and mineralogically.

8. The mass itself appears to have been a fragment dislodged from its native place, and, while perhaps not yet firmly rigid, to have been imbedded in the materials that now constitute the schist, and with them to have suffered the pressure and upheaval that have brought the beds into their present vertical position. If it had become rigid before it was placed in the schist, it might still, perhaps, have been compelled to take its ovate form by reason of pressure and the mechanical movements to which the beds have been subjected. Judging, however, from the general ovate form of all the jaspilitic lenticules, even the largest, it seems more reasonable to ascribe this shape to some forces or circumstances that attended its origination than to mechanical causes that operated afterward.

Revisiting the old pit of the Stone mine, and noting the so-called jaspilyte *dike*, illustrated in the 15th report (see p. 235), we observed another egg or jaspilyte similar to that just described, though this is partly disintegrated now so as to reveal an original brecciated structure, at least on one side. The harder part is perpendicularly banded jaspilyte. On its exterior is a layer of red shale about one and one-half inches in thickness. This egg is entirely isolated within the schist as shown by the following sketch, fig. 9, made on the spot.

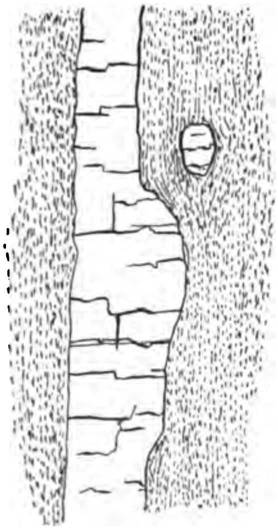
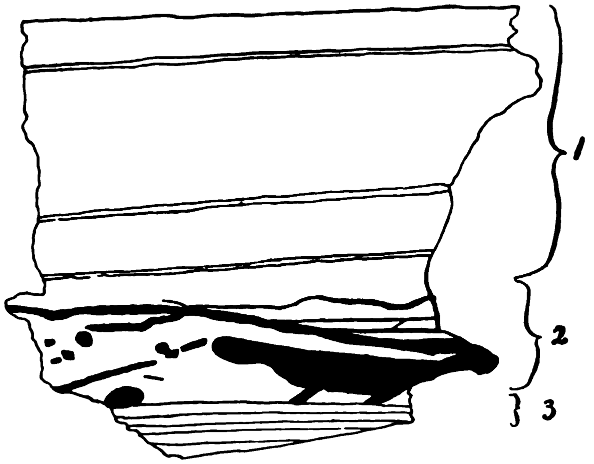


Fig. 9. Ovate lenticule of jaspilyte at the Stone mine, adjoining the "kike" of hematite.

A very interesting and instructive observation was made at the Stuntz mine, or No. 1. In some of the large angular pieces thrown out upon the dump is seen a singular sort of conglomerate and breccia. It is illustrated by the following sketch, likewise made on the spot, fig. 10.

In No. 1, by far the predominating ingredient is white, chalcedonic silica. The same is true of No. 3. No. 2 seems to have been suddenly introduced in the midst of a silica-forming epoch, and as suddenly to have ceased. This interruption caused the coarse fragmental transport of masses from some previously formed green schist and from the previously formed brown jaspilyte. The green schist pieces are somewhat rounded, as would be expected from their softer nature, but the brown jaspilyte pieces are angular.



Explanation of figure 10.

1. White chalcedonic silica, banded with a little pure hematite.
2. Conglomerate and breccia of green schist and brown jasper. The black parts show the shapes of the green schist pieces.
3. White silica and hematite.

This indicates some rupturing agent that acted on both rocks. Indeed, there are many evidences that a frequently recurring force, whatever it was, interrupted the quiet accumulation sometimes of the jaspilyte and sometimes of the schist, and tore up sometimes only the last laid-down thin layer, and sometimes larger thicknesses of the formed beds, and removed them to smaller or greater distances from their native places. This force acted in a common manner on both the acid jaspilyte and the basic schist.

There is hence much reason to suppose that all three of the known agencies for rock-forming were intermittently at work and concerned in the formation of the iron ore, viz.: *Eruption*, to afford the basic eruptive material; *sedimentation*, to arrange it (in the main), and *chemical precipitation* in the same water, to give the pure hematite and the chalcedonic silica. What was the cause of the chemical change in the waters of the Keewatin ocean that brought about the precipitation of silica and hematite, is matter for further research. An ocean, universal as the Keewatin formation, charged with silica in solution, a hot alkaline ocean, on the outburst of volcanoes, might, perhaps, be so far heated, and evaporated, as to be compelled to deposit silica as a chemical precipitate. On the other hand the introduction of cooler currents into the heated region would disturb the equilibrium of saturated solutions, and hematite (or limonite) might be the resultant precipitate. There is reason to believe the earthy, or semi-crystalline, schists of the age of the Keewatin are world-wide, and that, therefore, the ocean everywhere had, in general then, as now, nearly a constant character, only as modified by local or wide-spread volcanic agents.

By the railroad, just south of the Tower pits (Nos. 8 and 9), is a light greenish, novaculitic rock which dips N. 75 to 80 degrees (1557), It passes into graywacke. It is also highly siliceous with both chalcedonic and vitreous quartz, and has a fine white ingredient that gives it a feebly talcose feel, the last being the same element that we have called sericitic. The soft, light green (or white) mineral varies in amount from layer to layer, so that some of the sheets are smooth and soft throughout, and schistose, others being more like graywacke, and others almost a quartzyte in which the vitreous quartz grains can easily be distinguished from the chalcedonic, by their dark color, that is, by their absorption of light which falls upon their fractured surfaces.

I met Mr. W. G. La Rue, of Barraboo, Wis., and he gave me further evidence that there are really two quartzytes concerned, as already represented by me,* in the geology of the Gogebic iron region. One is that which is the foot-wall of the Colby and Aurora mines, and the other is that which Mr. La Rue describes, viz.: North from the Colby mine, near the bluffs of the gabbro range, which there are plainly visible rising as a series of hills within a mile or less of the village (Bessemer), he was employed to explore for ore by shafting for some parties who thought there was ore near the gabbro. He said that under the gabbro he found a quartzyte, and a sandstone, the two differing only in induration, one being more easily excavated than the other, both consisting of crystalline quartz. He shafted under the quartzyte in a conglomerate of iron ore, which seems to be comparable to that found in a similar situation at Ishpeming, Mich.,** and at Cascade near Negaunee, and after a time he found that the conglomerate turned almost at a right angle toward the north. He did not seem to know what was under the conglomerate, but he told me he found the quartzyte and sandstone together 235 feet thick. This was in the sw¼, ne¼ sec. 10, 47-46, Michigan. This is apparently the unconformable conglomerate and quartzyte that I noted at Bessemer, at the railroad, in a small exposure, in my sixteenth report.

IV.

THE AGE OF THE GABBRO.

In attempting to correlate these observations with those which have been made and recorded in previous years, there is some difficulty in fixing the stratigraphic place of the gabbro eruption. It was inferred by the Wisconsin geologists that the gabbro sheet was the bottom layer of the great Cupriferous formation, or Keweenawan, and this was accepted and has been followed unquestioningly by the writer in all previous reports and discussions of the crystalline rocks of the state. The age of the great Cupriferous formation, with its traps and conglomerates, in part at least, has been established, with increasing evidence and positiveness as on the horizon of the typical New York Potsdam—at least at the horizon of a quartzyte which overlies the Animike of the northwest.

Thus the gabbro sheet was carried to the same age. When the gabbro was found to be interbedded with a quartzyte in northeastern Minnesota, and to lie upon and overwhelm it, (the Pewabic quartzyte), it was a necessary inference that that quartzyte was the equivalent of the Potsdam—or at least of the bottom quartzyte of the Cupriferous—and hence must lie over the Animike, although at no place could the Animike be seen interposed between it and the gneisses of the Giant's range. When it was found that this quartzyte which is the principal iron horizon of the Mesabi range, shows evidence, in the region eastward from Pokegama falls, of passing below the body of the Animike strata, necessarily carrying with it the gabbro sheet, the idea that the gabbro has possibly been put into a wrong position is brought out prominently before the student of northwestern stratigraphy, and he is disposed to call in question the datum from which some important conclusions have been drawn.

---

* See 16th Annual Report. pp. 55-6.

** See the 16th Annual Report, pp. 44-47.

The gabbro sheet itself is a wonderful formation, both in geographic extent, and in vertical thickness. It is also wonderful in the diversity of lithological variations that it displays—*i e*, when it approaches the characters of a normal doleryte, or when it is interstratified with beds of sedimentary origin, or when it is modified by contact with them. Yet its persistence under erosive and atmospheric agents, and its great volume, causes it to appear prominently and suddenly, and frequently, giving it the reputation of greater area and importance than it deserves. This is rendered more marked by the fact that its line of outcrop is characterized by heavy drift deposits which have covered up the less persistent formations and hid from inspection their true relations both to the overlying and underlying strata. It was hence a very natural conclusion that its advent was the opening scene of that succession of eruption and sedimentation which is displayed in the Cupriferous formation and that the whole should be grouped together under that single designation.

It is the design of this chapter to call attention to some facts that indicate that the gabbro lies below the Animike, (Huronian black slate), in great part, and that the later trap eruptions, continuing through the Animike and the Potsdam, (*i. e.*, the Huronian quartzyte), probably constitute the age and the strata of the Cupriferous formation—the "Keweenawan" of the Wisconsin geologists In other words it seems as if the Keweenawan series, in its full scope, embraces not only the age of the Huronian, (Potsdam), quartzyte, but also of the black slates of the Huronian that underlie the quartzyte.

1. The most important and significant fact that bears on the stratigraphic position of the gabbro, respecting its relation to the Animike black slates, is its occurrence along a wide extent, reaching from Gunflint lake southwestward as far as to the railroad

crossing at Mallmann's, (at least), *next to and immediately south* either of the gneiss of the Giant's range or of the "greenstones" of the Kawishiwin, without the appearance of any of the black slates between them. There is an appearance of *quartzyte*, with olivine grains and with magnetite, geographically between the gneiss and the gabbro, the same being unquestionably the Pewabic quartzyte seen near Gunflint lake. This quartzyte sometimes is impure and limonitic, and seems to be the chief iron horizon of the Mesabi range. This near conjunction (which is sometimes apparently an exact contact) of the gabbro with the gneiss, and the absence of the Animike proper between them, has been supposed to be due to a local overlap of the gabbro beyond the strike of the Animike, covering it from sight, the idea being that the gabbro flowed back northward over older formations, and came on to the gneiss.

2. Although there has not yet been any careful microscopic examination into the differences between the typical gabbro (for instance that seen at Rice's point, near Duluth) and the eruptive rocks that overlie the Animike black slates at Gunflint lake and eastward to Pigeon point, it has been noted that there are macroscopic distinctions which ought to be explained in case of a supposed parallelism of one rock with the other. The supposition has been that they are stratigraphically and chronologically the same, and that the differences were only local and unimportant. It was this assumed parallelism and the evidently later age of the eastern outcrops (the "crowning overflow" of the Animike) which has led to the placing of the gabbro later than the Animike. There is absolutely no other evidence. If these two eruptive rocks are not contemporary there is not only no reason against but considerable evidence in favor of placing the typical gabbro (such as at Rice's point, and at Little Saganaga lake) below the body of the black slates.

3. Boulders of characteristic gabbro and of red syenite, and of quartz porphyry, occur abundantly in the later "traps" of the Cupriferous. The quartz-porphyry pebbles are so abundant as to constitute the well known thick beds of coarse conglomerate; and quartz-porphyry layers or lenticular *sheets* are interbedded between the trap sheets. This quartz-porphyry in some cases appears to have originated in its present condition of interleaved sheets during the time of the Cupriferous. This is observable at the mouth of Baptism river, and at the Great Palisades. At these points, however, owing to the proximity of bosses of gabbro rising above the rest of the country about, it is certain that those portions of the Cupriferous which contain the original quartz-porphyry beds, are near

the bottom of the formation. This is further shown by the existence, in the same region (at and near Beaver Bay), of large boulder-masses of gabbro in the trap flows, evidently derived from the neighboring gabbro hills. From this point, northward to the gneiss of the Giant's range, nothing is visible, in the form of rock *in situ*, except gabbro, or some "muscovado"-like rock described at some outcrops somewhat further west* by H. V. Winchell. The region is not fully explored, but it appears from all that is known, that there is nothing to be found of the typical, thin black slates of the Animike. It is as reasonable to infer that they followed after the gabbro flood, as that they preceded it. In case they followed after it, their typical characters were destroyed in this region by the frequent outbursts of igneous eruption, and they blended with the tuffs and shales and basic sheets that constitute, on the north shore of lake Superior, the lower portion of the Cupriferous formation. In case they preceded they must exist buried below the gabbro, as hitherto supposed.

4. In further consideration of the possible infrà-position of the gabbro mass, below the Animike proper, attention should be given to the record of the deep well at Duluth, as given in Bulletin No. 5, of the survey. The interpretation of the record, given on page 34, shows, below the gabbro, (which is found to be 220 feet thick), quartzyte and conglomerate beds interstratified with imperfectly characterized gabbro, the whole having a thickness of 67 feet. Then followed trap sheets, and fragmental tuffs, for a thickness of 89 feet. Then follows what was thought to be the Animike, "evidently the Thompson slate formation." In the light of the foregoing (Nos. 1, 2 and 3) however, and on reviewing the descriptions given of the drillings of this well (pp. 31-34), the writer considers it quite doubtful whether "the Thompson slate formation" is on the horizon of the Animike of the northwestern part of the state. The existence of a minutely granular condition in the quartz (Nos. 39, 46, 50), recalling the "chalcedonic silica" of the Keewatin, and of a distinct slaty cleavage not due to sedimentary bedding (Nos. 28, 36, 37, 53), and of hydromicaceous or sericitic schist (Nos. 28, 30-39), and kaolinic itacolumyte (No. 41) noticed and recorded when the writer was impressed with the expectation of finding Animike characters, must be admitted to point to the Keewatin schists and graywackes. There are other coincident descriptions of the outcrops about Thompson, to be found in the tenth annual report (pp. 12-31) which throw doubt on the supposed parallelism

---

*Seventeenth report, p. 90-91, Samples 387 (H).

of the Thompson slates with the Animike of northwestern Minnesota, viz:

1. Folia of quartz and slates, or schists interbedded, (p. 12, No. 454, p. 16, No. 466, p. 17, No. 472), is a character not known in the Animike.

2. There is a conspicuous perpendicular slaty cleavage in all parts which is not dependent on the sedimentary structure, a character not seen at all, or rarely, in the Animike in the northwestern part of the state.

3. The clay slates are frequently pyritiferous, (p. 18, No. 473.)

4. Feldspathic graywacke (often called gray quartzyte in the original descriptions) is a conspicuous feature in the strata north from N. P. Junction (p. 28, No. 504).

It is only intended here to make record of these reasons for hesitating before accepting the parallelism of the whole of the Thompson slates with the Animike of the northwestern part of the state, notwithstanding the fact that it has been accepted hitherto, both by the Wisconsin survey, the U. S. geological survey, and by the Minnesota survey.

5. On the supposition that the Animike black slates are involved in the Keweenawan, and, while overlying the gabbro, lose their typical characters at points further southwest, the interbedding of the Animike with beds of trap-rock, which is a common feature about Gunflint lake and on the shores of Loon lake, is easily explained, and indeed falls into place as one of the to-be-expected facts of such a period of recurring eruptions. It also obviates the necessity of a supposed change in the character of the eruptive rock, *i. e.* that the gabbro of Rice's point and Little Saganaga lake becomes, on Pigeon river, the dark or greenish trap-rock and the dioryte which inter-bed and characteristically overlie the Animike, forming the well-known "crowning overflow" of that region.

V.

Further Observations on the Typical Huronian, and on the Rocks about Sudbury, Ontario.

In the summer of 1889, on the occasion of the Toronto meeting of the Geological Society of America, the opportunity was improved, both in going and in coming, to extend a former acquaintance made with the rocks of the region north and east of lake Huron.* A resume of these observations was read before the Minnesota Academy of Natural Sciences at the October meeting, 1889. In order that the bearing of the following facts and interpretations may be understood by any who have not given close attention to the developments of Archean geology in the northwest during the last few years, a brief resume may be the best introduction.

---

* Compare the sixteenth annual report of the Minnesota survey.

It is well known that in the term Archean are included two groups of rocks, the Huronian and the Laurentian.[*] These terms are of long standing, and have been used in the geological literature of nearly all parts of the world, wherever geological research has been carried on in the oldest rocks. They were proposed by the Canadian geologists in 1855, and were in a few years adopted by the geologists of the United States, and they are yet found in nearly all of the text books of geology in use in this country, with the signification that the Canadian geologists have given them. It is not necessary to say here what inconsistencies were involved in this course of accepted nomenclature, nor what injustice was rendered to American geology by American geologists, nor what were the motives that apparently actuated the leaders of American geological opinion thirty or forty years ago. It is only necessary to say that *Huronian* was in conflict with *Taconic*, and that *Archean* was in conflict with *Azoic* as well as *Atlantic*, names that had been proposed earlier by United States geologists.

With the revival of work on the older rocks in the northwest, about ten years ago, it was found that the original Huronian of Logan and Murray had been amplified, by the reports of the later assistants on the Canadian survey, by an important extension of the names downward, over many varieties of rocks not mentioned in the Huronian region by those who first described the Huronian formation, and even over all the stratified, or schistose formations, down to the massive gneisses and syenites which are called distinctly *Laurentian*. This extension had also been accepted by many, if not by all, geologists of the United States. This was true of the late surveys of Michigan and Wisconsin, and of the earlier reports of the Minnesota survey, and was maintained, but haltingly toward the last, by Prof. R. D. Irving up to the time of his death.

In order to get a correct understanding of the character of the Huronian rocks of the original Huronian area, several recent re-examinations have been made of the area described and mapped by the Canadian geological survey. The first was that of Prof R. D. Irving, who came to the conclusion that the so-called Animike formation of Minnesota and Thunder bay (in Canada) is the equivalent of the original Huronian. But, unfortunately for the cause of correct nomenclature, Prof. Irving, who had embraced the expanded Huronian in his Wisconsin work, so continued his trip beyond the limits of the original Huronian, that he found, eastward from Algoma, a series of rocks which he thought also belonged in the same series with those at Thessalon, and so verified (?) his classification published in the Wisconsin report. Hence, while correctly assigning the real Huronian to its western equivalent (the Animike slates and quartzytes), he failed to see that outside of the mapped Huronian of Logan and Murray the name had no right to be extended over a different formation, for eastward from the mapped area another formation at once begins and hence, also, he continued to maintain that the Animike could be extended downward so as to cover all the lower schists and graywackes and iron ores of the Northwest.

---

[*] C. H. Hitchcock has called attention to the fact that G. W. Featherstonhaugh proposed the term *Atlantic* for these rocks many years before Prof. Dana introduced the term *Archean*, and before Foster and Whitney employed the term Azoic. See *American Geologist*, vol. V, p. 199. Also compare *Geology of New Hampshire*, vol. 1, p. 525.

Prior to this an unconformity and a profound change in lithology had been discovered between the Animike formation and the schists below it, in the vicinity of Gunflint lake; and, at a later date, those schists had been examined in the region of the Lake of the Woods, and while placed doubtingly in the Huronian by G. M. Dawson, and by Bell, had by Mr. A. C. Lawson been given a new name, (Keewatin) who exempted them, questioningly, from the Huronian system, showing that they pass unconformably below the Animike which had been said by Prof. Irving to be the real equivalent of the Huronian on the north side of lake Superior.

In the sixteenth report of the Minnesota survey will be found two other recent descriptions of the original Huronian rocks, from an examination made in the summer of 1887. Here the Huronian formation is distinctly limited to the strata described at first and named Huronian by Logan and Murray, and the name given by Dr. Lawson for the underlying schists (Keewatin) is adopted unqualifiedly, and extended over those schists in Minnesota. The same classification had been adopted also in the fifteenth report of this survey, but without the authentication that comes from a fresh examination of the old data.*

As the current idea of the Huronian, as at length extended by the Canadian geologists, began to be questioned, several re-affirma-

---

*The writer has reviewed the history of the Huronian system as expounded by the Canadian geologists, in the AMERICAN GEOLOGIST. *Methods of stratigraphy in studying the Huronian.* Vol iv. p. 342.

tions of its correctness have been published by Drs. Selwyn and Bell. It was in the light of these discordances that some recent re-examinations have been made, and the following notes were recorded when on a joint excursion with several geologists from the Toronto meetings of the American Association for the Advancement of Science, and of the Geological Society of America.

North Bay.—The rocks about North Bay,[*] on the northeasterly shore of lake Nipissing, placed in the Laurentian by the Canadian geologists, consist of dark-colored, micaceo-hornblendic gneiss, or gneissic schist. They are distinctly bedded by sedimentation, the characteristic belts of which run parallel for long distances. They are generally fine-grained and often red-weathering, recalling by this, as well by their structure and mineral composition, some gneisses seen and described by the writer in 1886,[**] on the Kawishiwi river. These are massive, fine-grained, red, very siliceous beds, as if from a quartzyte, but the most of the rock is closely laminated varying from very micaceous to very orthoclastic. The strata stand about vertical, but generally show some inclination southward—but sometimes northerly. The strike is about NW. and SE. Some of the gray gneiss (1573) which weathers reddish (1574) becomes contorted in some places and infolds, unconformably, masses of a dark rock very different from the gneiss (1575). These masses are wrapped round continuously with unbroken, but curved laminations of gneiss, the laminæ, at some distance from the enclosed masses, becoming straight again, and running in their usual course. These contrasted foreign enclosures have a different aspect, and a different composition from the micaceous belts of the gneiss. They are both micaceous and hornblendic, but mainly hornblendic; non-laminated and generally containing multitudes of fine crystals of cinnamon-garnet. In some places these masses are very large, and cannot be seen to be enclosed, but cut off the gneiss and replace it in large areas. The geology in general here recalls that of Northeast cape in Bassimenan lake (fifteenth report, p. 358), as well as that mentioned on the Kawishiwi river. The rock has been plastic *in situ* and molded about masses of foreign intruded rock, apparently a basic eruption, but has not been molten and extruded. In general the horizon to which it would be assigned in the Minnesota scale, would be near the bottom of the crystalline schists (the Vermilion series), or very near the Laurentian gneiss. It is very probable indeed that rocks like these have been included in the Laurentian in some of the descriptions and map-coloring in our reports. Since it graduates, in Minnesota, conformably on the one side into typical gneiss containing very much less mica, which would be placed unhesitatingly in the Laurentian, and, also, on the other hand, fades out by the loss of the black mica, and by the acquirement of a sub-crystalline and finally a fragmental texture, into the typical rock of the Keewatin, it is evidently only an arbitrary line of separation that can be drawn distinguishing it definitely from one or the other. The principal difference between it and the Keewatin consists in its more nearly perfect crystalline structure. The principal difference between it and the greater portion of the Laurentian gneiss in Minnesota consists in its greater percentage of black mica. The prevalence of the black intrusive masses oc-

---

[*] The rocks about lake Nipissing have been described in the Canadian reports by Alexander Murray, for the year 1854, for the year 1855, and maps of the atlas accompanying the volume.

[**] See the fifteenth report, Minnesota survey, p. 353.

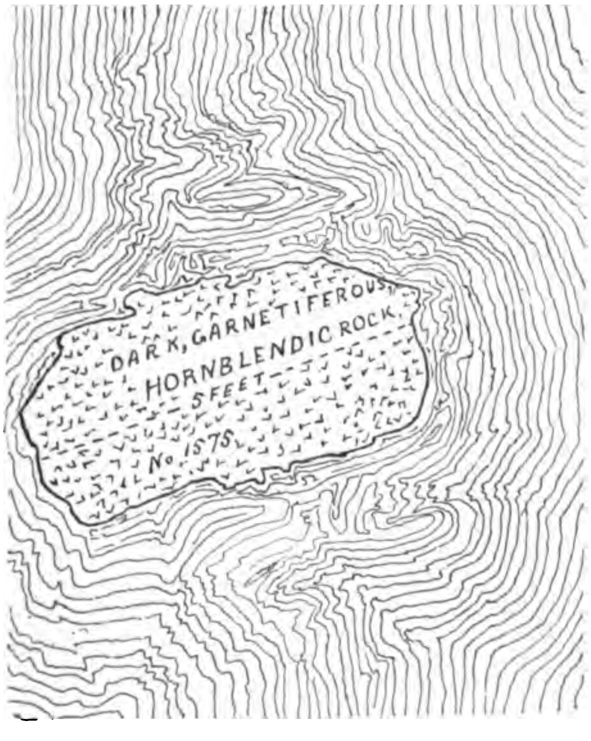


Fig. 11

Included hornblendic mass at North Bay, causing contortions in the gneiss.

Rock Samples obtained at North Bay are numbered as follows: 1573. Gray gneiss, the general rock at North Bay, after the weathered surface is removed. 1574, Reddish weathered gneiss, a surface condition. 1575, Hornblendo-micaceous and garnetiferous dark rock embraced in the gneiss (see figure 11) as foreign masses, and as large areas, the laminations of the gneiss being wrapped about them entirely and roughly conforming to their exteriors.

curring transverse to the strike of the gneiss, and in a manner involved with the gneiss, showing a mutually plastic condition of the two, is a characteristic of the Vermilion series about where the transition to the Laurentian occurs with an *eruptive unconformity*, the foreign intrusive rock being the dark, hornblendic masses and not the gneiss. The manner of occurrence of one of the smaller hornblendic and garnetiferous dark masses was sketched on the spot and the same is represented on page 51 (Fig 11). This was near the public school house at North Bay.

Wahnapitae. A sample of that which is here called Huronian by Dr. Selwyn is numbered 1576. At this point the formation changes from the Laurentian to the next higher, or supposed younger, formation. The train stopped but for a moment, but with difficulty a small sample of the country rock was procured. On examination it was found to be of a hydro-micaceous schist, silky-sericitic, evidently a part of the Keewatin. Subsequently Dr. A. C. Lawson re-examined this point, in order to get a better idea of the relations of the formations, and according to verbal description from him, there appears to be an unconformity of stratigraphy at Wahnapitae. similar to that at Penokee gap, Wisconsin; at the immediate contact the lower rock is the fine, micaceous gneiss, or mica schist, probably belonging to the series seen at North Bay, and the upper rock is quartzyte and gray argillyte interbedded.

At the Stobie copper and nickel mines, about three and a half miles north from Sudbury, there is a large exposure of greenstone, coarsely fibro-crystalline with hornblende (1579), seen south of the mines rising in high ridges and domes, resembling the ridges of the Kawishiwin greenstone of Minnesota (see the 17th annual report), though much more coarsely crystalline. This lies below the rock that contains the copper and nickel ores, and was fruitlessly penetrated by a costly shaft in pursuit of the ore-bearing rock several hundred feet. The present mining is done in a quartzyte (?) or at least a quartzose, apparently fragmental rock, which is superficially buried under a thick deposit of rusted debris, or gossan-cap, the result of its own decay. The ore permeates this gray granular rock in the form of sulphides which in this superficial layer is converted to oxides and carbonates. The mines are still not deep, although some tunneling has been done in the hillside. Outwardly the resemblance of the lithology of the lower rock (1579) to some of those described in northeast Minnesota belonging to the eruptive portions of the Keewatin is so great, that it is reasonable to suggest that it represents the lower formation. But the quarried rock cannot be assigned with any certainty to the same horizon. Its resemblance to some of the lower feldspathic, gray quartzytes seen in the Animike (Huronian), and its manner of occurrence in a low bluff apparently dipping at a low angle away from the lower greenstone, as well as the similar occurrence of abundant sulphides of iron (and nickel ?) in the lowest parts of the Animike west of Gunflint lake, caused me to regard the ore-bearing rock, on lithological evidence, as belonging to the true Huronian, and hence as unconformable on the other. Samples of the ore are 1578, and of the ore-bearing rock 1577.

At the Copper Cliff mine, three and a half miles s. sw. from Sudbury, according to Dr. Selwyn a dioritic dike (1581 and 1584) runs through the country, and the ore is associated with that. The next rock, on the north, is a red felsyte (1583), and the relations between it and the mined rock were not made out by anything I saw in the short time we were on the spot. The red felsyte becomes protogenic, or granitic, and also has fine black mica-scales developed in it in other places. The ore of this mine is represented by No. 1582. Eastward from the mine is a small knob of red felsyte, and next, about ½ mile from the mine, is a knob of coarse conglomerate in which there are large boulders of red-weathering felsyte like that at the mine, also of laminated fragments of a grayish rock like a fine-grained graywacke or coarse argillyte, and probably others. The matrix is gray and finely siliceous, of which No. 1585 shows an average.

At 1½ miles from Sudbury, toward Onahping, the train stopped for the examination of a peculiar rock (1586), recalling, but not identical with, the hornblende-porphyry of Kekekabic lake (No. 751), but having much coarser crystals, and a more evidently conglomeritic original structure. At ¼ mile further nw. this conglomerate is more crystalline, the matrix being reddish-weathering felsyte (1588), and the included masses being of a dark basic rock probably originally eruptive. In places this felsyte becomes granitic, and the large dark fragments appear as boulders and included masses more or less modified in shape, embraced as in a once plastic or molten rock. The aspect in such cases is much like some Laurentian, and if it were to be found to extend over a large area with these characters, it would probably be assigned to the Laurentian by any geologist. This illustrates one of the difficult problems involved in the use of the term Laurentian. This rock is in the midst of what passes for *Huronian,* and is derived from a fragmental rock which is like many seen in the "Huronian" of the region. It assumes first a porphyritic aspect, then it is felsitic, weathering reddish with a pronounced orthoclastic ingredient, then, with a coarser grain, it appears like an eruptive granite embracing masses of foreign basic rock. This is similar to some observations that have been made in Minnesota in the Keewatin, and particularly on the upper waters of the Kawishiwi river. Similar transitions have been observed in Michigan. *

At the Murray mine the ore (1589) is in a conglomerate, disintegrating and limonitic.

At Vermilion lake (*i. e.*, at the crossing of the Vermilion river), is a repetition of the falls, ridges and rapids seen at Thompson, Minnesota, the whole being manifestly of the same age, and supposed to belong to the Animike or true Huronian. The dip of these slates is 45° towards the S. Dr. Bell stated that the train, before arriving at Vermilion river, had passed over these slates for about five miles, viz; through a very flat and good agricultural tract, indicating a profound change in the underlying rock, inasmuch as, up to the place of entering on these slates, the country had been very rough, with frequent exposures of the rock. The slate is black, (or purplish black when dry), generally fine grained, yet with some evident grains of quartz, (No. 1590). In it are some curious calcareous bunches, or "concretions," which recall the soft masses in which Dr. T. Sterry Hunt reported evidences of a "keratose sponge," found near Thompson, Minnesota. Some of these masses are two feet in diameter, with rounded outlines, presenting on the weathered or glaciated natural surface a striking contrast with the rock which encloses them. They are locally designated "snow-shoe tracks." This brownish, calcareous material is represented by No. 1591.

From the Vermilion river, traveling still northwest, we passed on to a lower series of strata, the dip being to the south-southeast. This is a "slate conglomerate," (1592), and causes an immense ridge, 150 feet in hight, more or less. Into this rock Dr. Bell states that the slates at Vermilion river graduate conformably, and indeed so they seemed to do; and in this respect the succession seems to be like that seen in the region of the original Huronian northward from the Thessalon valley, as described in the sixteenth report of the Minnesota survey. This "black slate," therefore, and the underlying "slate conglomerate" should be considered as portions of the Huronian as described by Murray and Logan.

Immediately after passing this ridge of "slate conglomerate," the average surface level subsides again, and the country is more even. But the rock that succeeds to the slate conglomerate toward the northwest, is mainly a reddish felsyte, similar to that seen in the vicinity of Sudbury, and necessarily underlying the foregoing slate and "slate conglomerate." It is also broken up into irregular small knolls, and presents a confusion of dip and strike that contrasts strongly with the regularity of dip and strike maintained by the overlying formation. This formation seems to have supplied many of the felsitic and granitic boulders seen embraced in the slate conglomerate. There was no opportunity to make search for the immediate contact of the "slate conglomerate" on this rock, but if the observations that have been made recently in the area of the original Huronian, and on the Animike in Minnesota, be taken as guide, there would be found, on making such a search, a distinct overlap unconformity at such contact line.

---

* Compare the 15th and 16th Annual reports, Minnesota survey.

From this point (Onahping) the excursion car turned back, and although it was planned to make a stop at Wahnepitae bridge to allow those interested to inspect the contact there between the Laurentian and the "overlying" formation, a heavy and continuous rain interfered, and the car returned directly from Sudbury the same evening to Toronto.

After this excursion I had the pleasure and the benefit of a further examination of the original Huronian region in company with Dr. A. R. C. Selwyn and Dr. A. C. Lawson. We walked from Algoma to Serpent river along the Canadian Pacific railway,noting the rock cuts, and the following is the general result of my own notes.

Quartzyte extends from Algoma to about one mile east, when a greenish slate (1593) appears with a dip s. 10° w, 45°—65°. This is fine grained and sometimes cut by dioritic dikes of epidotic rock, like that at Bruce. Next appears at 1½ miles from Algoma,a dark-gray roofing-slate (1594), the cleaving and bedding dipping southerly at an angle of about 75°. Below this is an immense stratum of "slate conglomerate"(1595), (3d of Logan's map of 1863), which is charged with boulders of various kinds of rock, the most conspicuous being of red granite. We then met with a soft fissile argillyte (1596) which hardly has any remaining sedimentary banding, and in it are elongated lenticular sheets of silica, apparently chalcedonic (1597). This resembles some seen in the Keewatin but there could be seen no contact, as the exposure is in the form of an isolated ridge which passes below the drift on all sides, so far as ascertained. It seems to be not a part of the argillyte before mentioned. This stands, in some places, nearly vertical. Then comes on a great quartzyte member (1598), but this is quite different from that seen at Algoma, and in the Thessalon valley. It is uniformly very fine-grained, and is apparently Logan's "gray quartzite," the lowest included by him in the Huronian. It is at any rate the same as the *Missasaugui quartzyte*, so-called in the 16th Minnesota report, which was there supposed to be Logan's lowest quartzyte. It is gray within and weathers red. The railroad swings back and forth across the ranges of this rock, following the easiest route, and affords some good opportunity to examine it. It exhibits important differences from the upper Thessalon quartzyte. It is interbedded with abrupt transitions from hard,apparently chalcedonic (?) silica, or quartzyte,to fine chloritic schists, the beds of the quartzyte being from a foot to two feet in thickness, and those of schist from two to eight inches. This extends for at least four miles, with some interruptions, the road passing in general at an oblique angle across the strike of the formation. The beds are for long distances straight and parallel. At a distance the face of the rock recalls the regular and straight furrows of a plowed field,the schist weathering and washing out easier than the quartzyte. Such a view is seen on the south side of the track about four miles from Algoma.

At a point still further east the conglomerate recurs by the track. Here it holds quartzyte pieces like the quartzyte just mentioned, and also others of red granite, and numerous pebbles of bluish vitreous quartz. It also embraces pieces of nearly black argillyte (1599) which is soft and has a nearly white streak.

After an interval of nearly a mile and a half of no rock exposure, we encountered a low boss of fine-grained black mica-schist (1600); with siliceous veins running with the strike. Then we found some argillitic beds in which were some crumpled white sheets of apparently chalcedonic silica (1601).

After an outcrop of coarse quartzyte (1602) resembling somewhat the Thessalon quartzytes, but less granular, whose stratigraphic position we could not make out, on account of the interrupted nature of the exposures and the variation in the direction of the track, we noticed two dikes of more recent diabase (1603) cutting the slate conglomerate and running nearly coincident with the strike, and having a columnar structure about horizontal. Under the conglomerate here, *i. e.* just before reaching Cook's Mills, at the mouth of Serpent river, conspicuous outcrops appear of a fine mica schist (1604), which is probably the recurrence in force of the mica-schist before mentioned (1600). It is not bedded but massive, and becomes hornblendic, recalling some parts of the Vermilion series of Minnesota. This continues to Cook's Mills and forms the outcropping rock at the station and about the village. No positive observation was made on the stratigraphic relation of this hornblendic mica-schist to the slate conglomerate, but its place is assumed to be below the conglomerate because of the known relation of the Huronian (*i. e.* the described Huronian of Murray and Logan) to such rocks in other places.

SUMMARY OF THESE OBSERVATIONS.

It appears, therefore, that both northwest from Sudbury and eastward from Algoma there are two formations. The slate and the slate conglomerate in both sections constitute the upper formation. In the region northwest from Sudbury the underlying rocks are largely felsitic, but are also micaceous, and at the Stobie mines become hornblendic. These changes are identical with changes that are known to occur in the Keewatin in Minnesota. In the section eastward from Algoma the underlying formation seems to be the Missasaugui quartzyte with interbedding of green fissile schist, in part, and a mica schist varying to hornblendic schist, in part, the latter being further east.

There seems to be some irregularity in the order of succession in the section eastward from Algoma, bringing in several outcrops of strata that belong higher up in the series. If this be not illusory, and due rather to the winding of the railroad from north to south to avoid the hills, it may be accounted for by such faulting and upheaval as have been described in Minnesota, such as have produced the sudden, but indistinct, unconformities and transitions from the Huronian to the Keewatin, that have been described there. Further, the quartzyte which has been alluded to as the Missasaugui quartzyte, and supposed to be Logan's lowest gray quartzyte, is probably not his lowest gray quartzyte, but it is rather a constituent part of the Keewatin. It is allied in all its lithology no less than its persistent verticality to the Keewatin and seems to have been formed in the Keewatin ocean in the same manner as the jaspilyte beds of that horizon, *i. e.*, by chemical precipitation, the green schist layers showing such advent of basic eruptions or volcanic ash as could form chloritic schists in the same way as in northeastern Minnesota. The "lower gray quartzite," (No. 5 a), of the original Huronian, according to Logan's map of 1863, appears a few miles east of Thessalon at the lake shore, and there produces an unconformable contact on the gneiss of the Laurentian. This contact has been examined by Prof. Irving and more lately by Dr. A. C. Lawson, and they concur in the statement that the conglomerate is a pudding-stone of rounded masses, having a quartzyte matrix. There can be but little doubt that it is the same as that seen in the vicinity of Thessalon, and hence that it is the Thessalon quartzyte and *overlies* the slates and slate conglomerates, being near the top rather than near the bottom of the original Huronian. This mistake is apparently the same as made in eastern New York and in Vermont, where the granular quartz (?) and the Potsdam (or red sandrock) seems to overlap and hide from sight the formation immediately older, and lies in unconformity on a still older terrane—on the east on the gneiss of the Green mountains, and on the west on the gneiss of the Adirondacks. It caused the early geologists to question the existence of any such formation as the Taconic—that great series in which has been brought to light latterly a wonderful fauna of primordial life, and which extends from the Atlantic slopes to the western basis of the Rocky mountains. This overlap unconformity implies a sinking of the pre-existing land, and of the ocean's bed, bringing the later formed strata over the beach-limit that existed before.

We may conclude therefore that the observations that were made on the recent excursions confirm, at least do not contravene, the views lately set forth by Irving, Bonney and Lawson, and the conclusions published by the reports of the Minnesota survey, to the effect that the Huronian system, as now defined and understood by the Canadian geological reports, really embraces two or three formations; that one of these is the true Huronian, as at first described and mapped by Murray, another is the Keewatin of Dr. A. C. Lawson, containing the iron ores at Tower, Minnesota, and another is the series of crystalline schists which we have styled Vermilion series. In other places these three formations have been fully treated.* They are distinctly separated by lithology and unconformities that have been noted from Vermont to Minnesota, and

---

[NOTE.—At Algoma are occasional very interesting boulders (1605). They contain large (and small) rounded, whitish-green feldspathic spots which are distributed somewhat like porphyritic crystals, but they have not the angular periphery of crystals. They are in a matrix of ordinary diabase of dark green color, and the spots make the rock noticeable, their largest sizes being somewhat larger than an inch in diameter. Some of these boulders are put in the foundation wall of the great hotel which the Canadian Pacific railroad projected at Algoma, and that is where we saw them first. Mr. Selwyn recalled the dike cutting the Animike on the high ridge back of Silver Islet, as the only spot known where such rock is in place. This dike was visited in 1879 by the writer and his samples are numbered 601 (Tenth annual report, p. 56), but the crystals in the dike are distinctly angular and not noticeably greenish. These boulders are suggestive of the existence of such source in the country toward the north from Algoma.

Another common boulder at Algoma is constituted of quartz-pebble conglomerate, the pebbles in which are of that ambiguous character seen in the Missasaugui quartzyte—whether fragmental or of chemical precipitation. While the boulders themselves are referable to the Thessalon quartzyte, high up in the Huronian, the pebbles that compose so large a portion (1606) are referable to that unconformably underlying vertical quartzyte (the Missasaugui quartzyte) seen, as above described, a few miles east of Algoma.]

* See the Seventeenth Annual Report, Minnesota survey.

should no longer be included under a single term—at least not under the term Huronian, which at first had a correct and adequate definition embracing but one of them.

VI.

ADDITIONAL ROCK SAMPLES NUMBERED.

[Collected by N. H. Winchell, intended to illustrate his field notes in 1888 and 1889.

1501. Vein rock and pyrites, from the quartz vein supposed to be auriferous, at Eagle Nest lake, east of Vermilion lake; according to Robert Angst this also contains metallic copper. [See description of this vein in the 15th annual report, p. 32.]

1502. Chemical silica, Tower, embraced in considerable masses in immediate proximity to the chalcedonic, in the green schist.

1503. Chemical (granular?) silica, in a vein about half an inch wide running transverse to the green schist, Tower.

1504. Chalcedonic silica, immediately adjacent to 1503; reddish, in thin laminations.

1505. Some of the schist seen interstratified in argillitic slate at the low "slate" knoll south of the "south ridge" and west of Tower.

1506. Four samples showing the relations of the chemical silica to the hematite, at the Lee mine, near Tower.

1507. Brecciated jaspilyte, cemented by a finer breccia of the same. From a boulder, but fairly illustrating the beds in situ.

1508. Black schist with pyrite balls, at the pits at the N.W. base of Chester peak.

1509. On the top of Chester peak some small veins consist of chalcedonic silica, crossing the jaspilyte banding.

1510. At Ely; a sample of the green schist showing the forms of two boulders, and the darker green rock separating them.

1511. Amygdaloidal portions of some of the boulders, showing the tubes perpendicular to the surface; from the green agglomerate at Ely, at the railroad cut.

1512. Chalcedonic silica from veins and spots in the rock 1510.

1513. Vein matter in 1510, similar to 1501. Probably auriferous.

1514. Sample of the gneiss at the Hinsdale quarry, *i. e.*, in the Giant's range.

1515. Frazer's quarry, North Redwood P. O., near Redwood Falls, on the Minnesota river. Massive, gray, uniform gneiss, without bands of color.

1516. Same place. Gray gneiss, with alternating and intershading micaceous and feldspathic belts.

1517. Same place; samples showing much red orthoclase.

1518. Gneiss, with much red orthoclase. Morton quarries, near Redwood Falls.

1519. Gneiss, showing inclusion of a micaceous, "black rock." Morton quarries.

1520. From a granite mound on sec. 12, T. 111—38. Redwood county. A bedded granitic rock, showing no red orthoclase.

1521. The gray quartzyte at Pokegama falls on the Mississippi river near Grand Rapids. Compare 257 (H)—259 (H).

1522. The gneiss at the upper falls of Prairie river.

1523. Showing micaceous schist in alternations with the gneiss at the upper falls of Prairie river.

1524. Coarsely crystalline orthoclastic belts, from the gneiss at the upper falls of Prairie river.

1525. Reddish and chloritic mass wedged in the gneiss at the upper falls of Prairie river.

1525 (a). Spottedness shown on the quartzyte at Prairie river.

1526. Shows another spottedness. Here the rusty spots weather out and produce a pitted surface on the quartzyte; same place.

1527. Hematite and impure hematite, siliceous and jaspery. Prairie river falls.

1528. Rock shown at about the horizon of this hematite.

1529. Somewhat above 1528. Finely laminated or "streamed," also brecciated, jaspilyte, with some vitreous silica.

1530. Jaspilyte and hematite, closely intermixed, but not interlaminated. The red jaspilyte appears as a felsyte.

1531. Hematite at this horizon; about one-fourth is hematite.

1532. Some of the quartzite that underlies this ore is conglomeritic in patches.

1533. Red shale. Griffin's camp, N. E. ¼ Sec. 22, 56-24.

1534. Iron-bearing rock. The ore impure and in broken and irregular sheets; hematite.

1535. Same as 1534. Pit No. 2, but struck at 15 feet below the surface.

1536. Same as 1534. Pit No. 3. Struck at one foot below the surface.

1537. Slaty hematite, rather low grade (47 p. c. iron) N. W. ¼ N.W. ¼ Sec. 21, 56-14.

1538. Magnetic iron ore, Sec. 23, 60-23. Fleck's location; from John Beckfelt.

1539. Rock associated with 1538.

1540. Duluth; on the Weller road, about 1½ miles from lake Superior, but about 2 miles from the business part of Duluth. Gray, porphyritic gabbro, with a fine magma.

1541. Shows contact of the "red rock" on the gray rock 1540.

1542. Red rock, crystalline. with some light-green spots, from the Weller road, same place as 1540.

1543. Granular silica, appearing somewhat as if originally chalcedonic (see 519). Same place.

1544. Vein matter in gabbro, at Rice's point.

1545. Serpentinous vein matter in gabbro at Rice's point.

1546. Quartz crystals lining vugs in dense hematite. Lee mine, near Tower.

1547. Reddish, earthy-looking jaspilyte. Lee mine.

1548. Breccia of fine pieces of hematite, red jasper and quartz, somewhat stratiform. Lee mine.

1549. Tarnished hematite, appearing as if it might be some copper sulphide; Lee mine. Coatings; Lee mine.

1550. Finely banded (sedimentary?), whitish jaspilyte; Lee mine.

1551. Hard hematite, with included crystals of chalcopyrite.

1552. Piece of chalcedonic quartz mass, embraced in a boulder of Stuntz island conglomerate (agglomerate), near the Lee mine.

1553. Piece of gray quartzose pebble or gray "felsyte," contained in the same boulder as 1552.

1554. Pebble from the same boulder containing vitreous quartz.

1555. Matrix of this boulder containing the above pebbles.

1556. No. 1553 becomes porphyritic in 1556.

1557. Light colored graywacke, or novaculyte, greenish white, with distinct grains of glassy quartz: at the railroad just south of Tower pit (Nos. 8 and 9). Dips N. about 75°—80°.

1558. Green schist, south of the Stone mine, at the railroad cut.

1559. Interbedded jaspilyte in 1558.

1560. Fine grains of disintegrated white jaspilyte; dump of the Stone mine.

1561. Breccia of jaspilyte and of hematite cemented by chemical silica; dump of the Stone mine.

1562. In the dump of the Stone mine some of the quartz crystals are superficially roughened and corroded—some of the fine crystals. What caused it?

1563. Green shale breccia; from the dump at the scram southwest of the Breitung mine.

1564. Botryoidal limonite on quartz crystals and on hematite; same place.

1565. Flinty, gray to dark gray jaspilyte, from the dump of the hoisting-shaft of the same place. Compare 866 B. and 1277.

1566. Rotted, angular masses of jaspilyte as intersected by the water-bearing course of a joint crossing a mass of contorted jaspilyte, at the Breitung mine.

1567. Pebbly conglomerate, embracing small grains of vitreous quartz; a patch or belt in otherwise typical jaspilyte. In the ridge that remains separating the Breitung from the Tower mine.

1568. A jaspilyte egg, somewhat concretionary, at least indistinctly concentric in some color bands. From the cut made for the high tunnel running south from the Tower pit (No. 9), where it crosses the light "ore streak."

1569. Coarse graywacke, rather soft, taken from the roof of the same tunnel, crossed by some thin veins of chalcedonic silica, about 15 feet from the southern entrance.

1570. From the dump, Breitung mine. What is the fine red mineral in crystals?

1571. Siliceous "green schist" interbedded in jaspilyte north of the Tower mine.

1572. From the jasper at the east end of the Stuntz mine. What is the white cementing vein-mineral? It appears to be granular silica, but also shows apparently cleavage surfaces.

1573. Gray gneiss, the rock at North Bay, on lake Nipissing, Ontario, in general, after the weathered surface is removed.

1574. Reddish-weathered gneiss, a surface condition of the rock at North Bay, Canada.

1575. Micaceo-hornblendic, garnetiferous rock embraced in No. 1573, as foreign masses, some of them fifteen feet across.

1576. Hydro-micaceous schist, silky-sericitic, from the "Huronian" at Wahnapitae, Ontario.

1577. The rock that contains the nickel ore at the Stobie mines, near Sudbury, Ontario, a gray quartzyte resembling the Pewabic quartzyte of Minnesota. Compare 1322 and 1340.

1578. The ore from the Stobie mines, Ontario.

1579. The "hornblendic rock" from the dump of the deep shaft which was abandoned at the Stobie mine, Ontario.

1580. Orthoclase found in veins in 1579.

1581. The dioryte dike which is supposed to cut the country rock at the Copper Cliff mine, Ontario. With this the ore is in some way associated.

1582. Ore of the Copper Cliff mine.

1583. Red felsyte, adjoining 1581 on the north.

1584. The conditions of the mined rock and the sulphides at Copper Cliff mine, Ontario.

1585. Matrix of a coarse conglomerate with boulders of red-weathering felsyte, one-quarter of a mile east of the Copper Cliff mine, north of the railroad.

1586. Porphyritic rock, the disseminated crystals being of hornblende and coarse. At the railroad cut, a mile and a half from Sudbury, toward Ohnaping.

1587. Dike-rock, cut by the grade, near the same place.

1588. Somewhat granitic felsyte, enclosing masses of dark basic rock in a manner like those at North Bay; reddish weathering; a quarter of a mile further toward Ohnaping.

1589. Ore of the Murray mine, Ontario.

1590. Black slate, Vermilion river, at the railroad crossing.

1591. Calcareous "concretions" in the black slate at Vermilion river. Same place.

1592. Slate conglomerate, N.W. from Vermilion river; from a ridge that rises perhaps 150 feet above the railroad.

1593. A mile and a quarter east of Algoma, on the north shore of lake Huron. Green slate, dipping S. 10°, W. 45°-65°.

1594. A mile and a half east of Algóma. Roofing slate, gray to black.

1595. Slate conglomerate, 3d of Logan's map. Underlying 1594.

1596. Soft argillyte, with lenticular spots and laminations of chalcedonic silica, next east of the slate conglomerate of 1595.

1597. Supposed chalcedonic silica, from 1596.

1598. Fine grained quartzyte, about 4 miles east of Algoma.

1599. From the great "slate conglomerate" east of Algoma, at a point east of the last.

1600. Fine-grained, nearly black, mica schist; at a mile and a half east of the last.

1601. Crumpled, white, apparently chalcedonic silica, from some argillitic beds east of 1600.

1602. Coarser quartzyte, still farther east.

1603. Dike-rock, cutting conglomerate.

1604. Hornblendic schist, Cooks Mill, at mouth of Serpent river.

1605. Diabasic boulders, with coarse feldspar crystals. Found at Algoma (compare 601).

1606. Quartz-pebble conglomerate boulders. Algoma Mills.

VII.

AMERICAN OPINION ON THE OLDER ROCKS.

CONTENTS. Page.

INTRODUCTION 65
1. EBENEZER EMMONS 68
2. DOUGLASS HOUGHTON 87
3. EDWARD HITCHCOCK 92
4. HENRY D. ROGERS 101
5. JAMES HALL 106
6. SIR WILLIAM E. LOGAN 112
7. JOSIAH D. WHITNEY 140
7. THOMAS STERRY HUNT 150
9. GEORGE F. MATTHEW 156
10. CHARLES H. HITCHCOCK 157
11. THOMAS BENTON BROOKS 169
12. NEWTON HORACE WINCHELL 175
13. CARL ROMINGER 188
14. ROLAND DUER IRVING 195
15. ANDREW C. LAWSON 208
INDEX 220

With incidental citations from Chester Dewey, W. W. Mather, L. Vanuxem, James H. Safford, William B. Rogers, Alexander Murray, J. J. Bigsby, J. Barrande, A. R. Selwyn, J. B. Marcou, Robert Bell, L. W. Bailey, Thomas Macfarlane, J. W. Dawson, C. T. Jackson, J. W. Foster, M. E. Wadsworth, C. R. VanHise, T. C. Chamberlin, James D. Dana, Charles D. Walcott, and others.

By ALEXANDER WINCHELL, LL.D., F.G.S.A.

INTRODUCTION.

As preliminary to a careful inquiry into the nature, arrangement and geological history of the older rocks of North America, I desire to collate the views which have been recorded by competent geologists during the last half century. Such a synopsis of opinions which have marked the progress of our science and have brought it through many labors, conjectures, errors and successes, to the very creditable position which American geological science holds at the present day, will greatly facilitate the work which remains to be done, by placing within convenient reach, the chief data of such progress, with copious references to the documents from which the information is drawn. Such a compendium of historic data will prove especially useful to geologists who have not the leisure to look up and digest the original documents. Since however, compilations of opinion, though offering opportunities for condensation, and even improved lucidity of statement, must necessarily lie under the suspicion that the author's view has been presented with incompleteness or with unintended coloring, the writer has deemed it best to present opinions generally in the exact language of their authors.

The present attempt bears some resemblance to that of Messrs. Whitney and Wadsworth in "Azoic system"*; but it will readily be seen to have a different aim, and to produce results far from identical. Their controlling purpose was, to prove, from citations, that during the time which has elapsed since the "Azoic System" was proposed by Foster and Whitney, no facts have been reported rendering it necessary to conclude that the "Azoic System" as conceived by them, is not both azoic and indivisible. My purpose involves an examination of such a position, but it involves much more. I propose to adduce the facts without the influence of an unalterable predetermination. I propose to select them impartially—rather in the interest of the writers than in the interest of any theory. I propose to give them an unbiased interpretation or to leave them without comment, to be interpreted by the reader. Beyond all this, it is proposed to cite many opinions not bearing on questions of taxonomy and nomenclature—opinions on all subjects whose agitation has taken part in the progress whose fruits we en-

---

*J. D. Whitney and M. E. Wadsworth, *The Azoic System and its proposed subdivisions*, Bulletin of the Museum of Comparative Zoology. Geological Series. Vol. I, pp. xvi and 331-565.

joy—problems of structure, superposition, metamorphism and geognostic evolution in general.

The method of Whitney and Wadsworth is geographical; mine may be denominated personal; neither traces consecutively the evolution of an idea or concept. Concrete methods have peculiar uses; and it is hoped the method here pursued may be useful as complementary to theirs, even if its subject matter possesses fewer advantages than I anticipate.

In some of these respects the method of the following sketch resembles that of Dr. Hunt in his Historical Introduction to the Azoic Rocks*. It differs, however, in the important feature of giving the views of investigators in their own language. One does not feel certain, in reading the memoir of Dr. Hunt, that he gets exactly the meaning of the original statement. In some cases, it is certain, the meaning is inadvertently colored, or even reversed. Dr. Hunt's treatment also, seems to the writer, deficient in method. It lacks consecutiveness; it abounds in repetitions; the connection of parts is more verbal than logical. The order would seem rather to be that of association of ideas in the author's mind than one determined by the logical or historical relation of topics. For such reasons, it is difficult to follow and comprehend. However this may appear to others, it seems certain that comprehension and clearness of conception must be facilitated by following the growth of conviction in each investigator's mind separately—introducing the biographical element into the history of geological ideas.

In the history of this advance, it has been the fortune of some to observe nature in the field, of others, in the laboratory, of still others, to collate records in the library—and I need hardly remind the reader that the efforts of many others have been expended in provinces not entered in the present discussion. Those who have worked in the field have supplied the greatest volume of records suitable for use in the compilation which follows.

In attaining the status which has been achieved, there must have been many false steps taken—erroneous observations, false interpretations, hasty generalizations, untenable suggestions, ill grounded theories, all mingled from time to time, with the influence of the "personal equation." Still, it is safe to assume that every investigator has been actuated by a controlling love of truth, and has done perhaps, as well as any other investigator would have done in precisely the same circumstances. If any have lost patience with a fellow-worker, it is profitless to reproduce the sarcasm in which impatience has found relief. The language of scorn or contempt has contributed nothing to the noble progress which we contemplate.

---

*Report E, Second Geological of Survey Pennsylvania.

As intimated, the present summary of opinion sustains a special relation to the contemplated sequel of the present memoir. Whatever its separate value may be, its use to the writer consists in the light which it sheds on an investigation to a large extent original. Circumstances have turned the writer's attention, during a few years past, toward the study of the older rocks. Though from boyhood familiar with the forms and aspects of the crystalline and sub-crystalline masses of Dutchess, Litchfield and Berkshire counties; though officially connected with public surveys over the crystalline expanses of Michigan; though long since a student of similar rocks in Missouri, Massachusetts and Maryland, it is true that the present research has been in a field comparatively new, and conducted by methods in part unknown to the older investigators, and but imperfectly mastered by most of us. It has seemed to the writer that one of the fields in which he has studied presents the problem of the older rocks under simplifications which promise advantages not enjoyed by the older students of terranes of high relative antiquity. Perhaps he deceives himself in thinking these advantages have brought him—a comparative novice—into possession of glimpses of truth which have been hidden from abler, but less fortunate students. He hopes however, the result will justify his confidence.

EBENEZER EMMONS.

1824. Ebenezer Emmons, in 1824 a pupil of Dr. C. Dewey, was associated with the latter in the preparation of a geological description and map of Berkshire county, Massachusetts, and of a small part of the adjoining states.[*] In this description the rocks are arranged in the following order (the whole being here inverted):

3. Transition limestone, &c.
2. Quartz, Primitive limestone, Primitive argillite (Upper Primary).
1. Granite, Gneiss, Talcose slate, Mica slate (Primary).

The second division indicates the elimination of the "Taconic idea" eighteen years before it received a formal designation.[**]

---

[*] *American Journal of Science and Arts*, Vol. 8, 1824, pp. 1, 240. An abridgement of this was included in "A History of Berkshire County," in 1829.

[**] 1819. In a "*Sketch of the Mineralogy and Geology of the vicinity of Williams College*" (*Amer. Jour. Sci.*, Vol. 1, p. 327, ii, 246, 1820.) Dr. Dewey had already published the germinal conception of the above arrangement, and of the Taconic system. The rocks and minerals were arranged in the following order: 1. Granite. 2. Gneiss and Mica

1837. At the end of the first season's observations within the Second Geological District of New York, professor Emmons described the rocks, in the nomenclature of the day, as Primitive, Transition and Tertiary.* Under the first, he describes first, Granite, which is "not strictly speaking, granite; that is, it is not composed of quartz, feldspar and mica; neither is it a true sienite, for even the hornblende disappears almost entirely for miles. It is mostly feldspar. . . . It contains the beautiful Labrador feldspar . . . often in large masses. . . . The color of the rock is usually grey, greenish or bluish. . . . It rarely contains quartz. . . . In Essex county it forms mountain masses. . . . The other primitive rocks of the northern counties are gneiss, hornblende and granular limestone. The talcose and mica slates rarely occur." The following is the succession reported, arranged here in descending order:

TERTIARY, consisting of grey sand and marly clay, with shells of recent aspect.

TRANSITION ROCKS. 1. Calciferous sandrock, including Potsdam sandstone. 2. Transition or blue limestone.

PRIMITIVE. Granite, Gneiss, &c.

1838. Professor Emmons again ranges the rocks of St. Lawrence county as Primitive, Transition and Tertiary†. The Primitive region he also designates "the gneiss district," but he states that "the rock is not purely gneiss," but only "the predominant rock," the region embracing also "granite, limestone, sienite, hornblende, steatite, serpentine, &c." The granite, he says, "occurs in beds and veins subordinate to the gneiss; . . . in huge angular beds or protruded masses; in the form of veins branching irregularly into the adjacent rock, and in overlying masses analogous to overflowing lava currents or greenstone." He speaks of it as sometimes "interlaminated with gneiss or other rock," but considers such position "accidental" (p. 196). The granite and gneiss contain in places, more or less carbonate of lime, or of lime and magnesia. The "primitive limestones" he speaks of as interstratified, but is particular to discriminate them from the marbles of Vermont and Massachusetts, "especially those of Berkshire county."‡ He gives eleven diagrams to illustrate the position that

---

slate. 3. Quartz. 4. Granular limestone. 5. Argillaceous slate. It will be noted that there is one limestone formation. These views were adopted by Prof. Amos Eaton in his "Index to the Geology of the United States," 1820, though later, he became an indefatigable original observer. (*Amer. Jour. Sci.*, xiv, 147, 1828.)

**First Annual Report*, New York, 1837, Assembly, No. 16, pp. 109-117.

†*Second Annual Report*, New York, 1838, Assembly No. 200, pp. 194-217.

‡This is further insisted on, p. 232.

we have the same evidence of the igneous origin of the primitive limestone as of the igneous origin of granite—that is, it occurs interbedded, penetrating and ramifying in relation to the granite.[*]

The sandstone at Potsdam is said to rest directly on the primitive rock, but it is no longer identified with the "Calciferous sand rock" of Eaton, (p. 214). On page 217, it is called for the first time, "the Potsdam sandstone" (pp. 217, 230.)

Treating of Essex county he speaks of the granite as "composed essentially of Labrador feldspar and hypersthene," and decides to style it "Hypersthene rock" (p. 220). It contains extensive beds of iron ore, sometimes branching and vein-like. The primary limestone "uniformly occurs in veins" in the hypersthene rock. The gneiss of the country is limited in extent, is interlaminated with saccharoidal limestone, and contains beds of magnetite and hæmatite (p. 221).[†]

We have no documentary evidence of the progress of the evolution in Dr. Emmons' mind previously to the publication of the Gazetteer next to be mentioned. But professor Dana has recorded the fact[‡] that, according to information from professor James Hall, a discussion of "Taconic ideas" took place at the meeting of the "Association of American Geologists and Naturalists" at Philadelphia, in April, 1841. In this, Dr. Emmons was opposed by H. D. Rogers, E. Hitchcock, W. W. Mather and James Hall, while Lardner Vanuxem favored his views.[‖]

---

[*] Numerous other reputable geologists have entertained the same rather remarkable opinion—von Leonhard, Giudini and Rozet.

[†] The Tertiary beds are of some considerable extent, occupying "not only the Champlain valley but that of the St. Lawrence and Hudson also." He notes it as a "marine formation," and states that "above these clays, &c, we have the modern group composed of boulders, pebbles and sands" (238). Emmons here bestows the names "Mt. Marcy" and "Adirondack group" or "Adirondacks"—the latter to embrace the high summits of northern New York. (pp. 242, 243).

[‡] *Amer. Jour. Sci.* III., xxxvi, 412.

[‖] The Proceedings of this Meeting are found in the "*Trans. Assoc. Amer. Geologists and Naturalists*, 1840-42. but this discussion not having been reported, no mention of it appears, under a rule of the Association. The proceedings are reported also, in *Amer. Jour. Sci.*, xli, 158, 1841. The grounds of Vanuxem's defence are stated in *Report on the Third District*, 1842, pp. 22-23. He styles it "The Taconic or Intermediate System," and says, "the Cambrian System holds the same position." Mather's reasons for regarding the Taconic rocks as a metamorphic condition of the Champlain rocks are given (p. 438) at the close of a chapter on the Taconic system; also p. 464 (*Report Third District of New York*, 1843, pp. 422-438). Professor Hall in his report on the Fourth District, embraces the Taconic system in his enumeration, and nowhere expresses any dissent.

"The comparison of views at the meeting", says professor J. D. Dana, (*Amer. Jour. Sci.*, III., XXXVI, 413, Dec., 1888) "resulted in inducing Prof. Rogers and Prof. Hall to take the field for the study of sections over the Taconic region. The season had just passed when Prof. Rogers made a report on his results to the American Philosophical Society at Philadelphia (*Proc. Amer. Phil. Soc.*, Jan., 1842) sustaining the views which Hitchcock, Hall, Mather and himself had before favored".

1841. A communication appeared from Dr. Emmons on "The Geology of Montmorenci,"* which, according to Dr. Selwyn, "seems to be of considerable interest and importance, in view of recent discussions." It supplies some of the evidence on which Dr. Emmons determined the existence of a great fault, reaching from the St. Lawrence into Vermont and New York. On the highway from Quebec to the falls, at the Beauport river, a regularly bedded, horizontal, nearly black limestone outcrops, "presenting a remarkable contrast with the highly inclined rocks of Quebec." A "black slate," also, "apparently rests against" the limestone. A fault or uplift is thought indicated by the facts here observed," along the line which the road passes." The first outcrop is" very clearly Trenton limestone," and "the slate is the Hudson River slate."

At the fall, the bed of the river above, is gneiss. Reposing horizontally on its edges, is, first, the Potsdam sandstone, stained with copper, and not over ten feet thick; second, coarse bowlders, as at Chazy, N. Y., considered the upper portion of the Potsdam; third, "a compact limestone" conformably overlying, containing encrinites. This "graduates into a gray, crystalline limestone," with broken encrinites. Succeeding this is the Trenton, 60 or 70 feet thick. The absence of the Calciferous and Chazy is noted; though this is not considered remarkable.

Below the fall, the rock forming the fall is seen to be fine-grained gneiss. Against this, the Black slate of the Hudson river reposes, but with an unconformable inclination. Dr. Emmons recognizes here a fault, with an uplift on one side "and a down heave on the other, by which the slate has been thrown into an inclined position."

This fault is regarded as extending south along the Beauport road, and even into the state of Vermont; and "may be particularly traced on a line connecting Johnson's mountain in Lower Canada, several points on the Missisque bay adjacent to the Provincial line, and also, at the remarkable uplift at Snake mountain, in Addison, Vt. A line uniting those points and several others in the same direction, marks the line of a great disturbance which has deranged the lower Transition rocks for at least four hundred miles."

In view of these facts, Dr. Emmons asks; "May not the great fault have caused the confusion in the writers on geology, in re-

---

*The *American Magazine*, November, 1841. See this reproduced in *American Geologist*, ii, pp. 94-100, August, 1888. The date of this paper was wrongly printed in the *American Geologist* at first, but was corrected afterward (vol. iv, p. 387).

gard to the lower Transition rock, particularly the Hudson River slates and shales? May not the same derangement exist in England and Wales, and have been the cause, at least in part, of their separation from the Silurian system, and of their being considered as one distinct therefrom, and which has been called the Cambrian System?"

He speaks of the horizontal position of the Hudson River rocks at Pulaski, Lorraine, Rodman and Pinckney, in New York, conformable with the Silurian system; and of their inclined position in Rensselær and Washington counties, in Vermont, and the entire length of Lower Canada. In the latter region, they agree with the Cambrian (omitting the lower portion.) He speaks of this as a conviction of long standing.

He continues: "It is proper to notice here one source of difficulty in regard to the rocks of the Hudson river, especially on their eastern border. It is the fact of their overlapping in this direction, the Trenton limestone and the other Transition rocks beneath. The consequence has been that, in traveling from east to west, or from Massachusetts and Vermont to New York, we pass directly from the Primary mass to the higher members of the Transition system; consequently they [geologists] have placed them upon the Primary, and considered them as the lowest of the Transition; whereas there intervenes between the Hudson river slates and the Primary, the Trenton limestone, the Birdseye, Calciferous, and Potsdam sandstone, the aggregate thickness of which exceeds a thousand feet. Not one of the lowest members of the Transition system appears in the eastern prolongation, between the Highlands of the Hudson and the Highlands north of Quebec, adjacent to the Primary, in consequence, as has already been said, of the overlapping of those rocks formerly termed Greywacke, or now known as the Hudson river series, to the talcose slates of the Primary, and also, the great correspondence in kind and amount of their dip."

Speaking of the tenuity of the Hudson River rocks where found horizontal, and their great thickness where inclined—amounting to 20 or 25 miles—he says:—"There can be no doubt that east of the Hudson, there are numerous repetitions of the same layers; for it cannot be supposed for one moment, that any of the formations above the Primary, can be of this enormous thickness which observation seems to indicate."

1842. While occupied in the preparation of his final report on the Second District of New York, Dr. Emmons drew up an article on the "Topography, Geology and Mineral Resources of the State of New York", which was published in March, 1842.[*] In this article he says: "The rocks (upon the eastern border of New York, adjacent to Vermont, Massachusetts and Connecticut) are situated between the gneiss of Hoosick mountain on the east and the slates of the Transition on the west. They occupy, therefore, geographically, as well as geologically, an intermediate position–the rocks on the one hand bearing a very close resemblance to the Primary on the east, and on the other, a great similarity to the Transition slates on the west. Still, as a whole, the rocks of the Taghkanic range may generally be distinguished from those on either side, their general character being derived from the presence of a large proportion of magnesia, which imparts to the rocks a softer feel and a peculiar greenish color. It is not proposed in this plan, to separate these rocks from the Primary, but to consider them as belonging to the upper portion, and to speak of them as the Taghkanic rocks, or perhaps as the *Taghkanic System*. . . Considering them for the present, as belonging to the upper portion of the Primary, the Taghkanic rocks will be composed first of a peculiar talcose slate, or a magnesian slate in part; in other parts, it is plumbaginous, which strongly soils the fingers. . . Second, of white, gray and clouded limestone, varying in texture from fine to coarse-granular, often interlaminated with slate, the latter often merely coloring the limestone, so as to impart that clouded appearance . . . Third, of granular quartz, or a sandstone generally silicious and of a brown color . . . The whole *Taghkanic System* is clearly stratified, and is wholly unconnected with gneiss, serpentine, granite, sienite, steatite or hornblende . . . "

This distinct announcement of the Taconic System, it will be observed, appears in a volume printed in March, 1842. It must have been drawn up, probably, some months previously. Professor J. D. Dana, by a slip extraordinary for him, has quoted a passage from Mather's Fifth Annual Report[†], the meaning of which is that the writer, on January 20, 1841, (Dana says Febuary 1, 1841), regarded the "granular quartz" (embraced in the Taconic) as simply "the Potsdam sandstone in a metamorphic state", and the associated "granular limestones" as belonging to the same geological epoch", and that "the rocks generally along the eastern border of New York, and probably all the rocks from the New York State line east to the Connecticut valley are similar". But these, it appears, were not Emmons' views on the first of February, 1841. The conception of the Taconic system was not originated in the brief period between this date and January 1, 1842—the date of Emmons' final report. The citations already made from the geology and map of Berkshire county show that the body of rocks between the Primary granites, gneisses and schists, and the Transition rocks above, had been isolated eighteen years before, though at that time designated "Upper Primary". If Emmons made no mention of them in his annual reports, it was because they were not embraced in his district. In a final report, however, he tells us he felt constrained to carry into effect a plan formed in the beginning of the survey, "to furnish the materials necessary for a complete work on the New York rocks" and to make "this volume distinct from, and independent of, the reports of the other districts"[*] In another connection he informs us that the conception of the Taconic dates from 1838.[**]

---

[*] *A Gazetteer of the State of New York*, etc., Albany, 1842. J. Disturnell, March, 1842, p. Attention has been called to this and other early literature bearing on the Taconc system, by Lieut. A. W. Vogdes, in the *American Geologist*, vol. II, 1888, pp. 352-55.

[†] *Amer. Jour. Sci.*, III.XXXVI,411, beginning, "The granular quartz of Bennington".&c.

In his Final Report on the geology of the Second District,[†] Dr. Emmons gave the following classification of the Primary rocks:

I. UNSTRATIFIED.	II. STRATIFIED.	III. SUBORDINATE.
1. Granite	1. Gneiss.	1. Porphyry.
2. Hypersthene rock.	2. Hornblende.	2. Trap.
3. Primitive limestone.	3. Sienite.	3. Magnetic, and
4. Serpentine.	4. Talc or Steatite.	4. Specular oxide of iron.
5. Rensselærite.		

The granites are recognized as erupted at different epochs. The hypersthene rock contains disseminated grains and extensive beds of magnetite (p. 222). The primitive limestone is still regarded as unstratified and igneous in origin (pp. 38, 225). Adverse opinions are examined, and new evidences adduced. Serpentine is also alleged to be never stratified, and to have been erupted, probably, at different epochs (pp. 69, 70). Yet it never occurs in dikes or veins, and causes no alteration in contiguous rocks. The same opinions are entertained of Rensselærite (p. 74). "The term sienite is applied to a stratified rock composed of feldspar and hornblende" (p. 80). The magnetic and specular oxides of iron are regarded as of igneous origin (p. 97). Of the origin of the stratified primary rocks nothing is here recorded.

The seventh chapter of this volume (pp. 135-164), is devoted to the "Taconic System," though none of the rocks have been observed to occur in the Second District of New York. "A large portion of its rocks or masses are interlocked between the New England or primary ranges upon the east, the most important of which is the Hoosick mountain, and the Taconic (range), with the more westerly abrupt hills, upon the west—or the eastern border of the New York Transition system." On each side, the rocks partially blend with the contiguous systems. The lower limit of the Taconic system is the upper limit of the Primary. The statement that "these rocks belong to the earliest deposits" (p. 141) would imply that gneiss (of the Primary) is not regarded as sedimentary in origin[*]. The upper limit of the Taconic system is the Potsdam sandstone—which at this epoch was regarded as the base of the fossiliferous series, or at least of the Silurian series.

---

[*] *Report, Second Dist.*, 1842, p. 135.

[**] *American Geology*, Pt. II, pp. 5 and 6.

[†] *Geology of New York*, Part II, 1842, p. 23. This was published May 26, 1843.

The formations here embraced in the Taconic system are the following, in descending order:

5. Stockbridge limestone, coarse granular and of various colors.
4. Granular Quartz rock, generally fine grained and brown, but sometimes white, granular and friable.
3. Magnesian slate having a soft feel. Principal mass of Taconic mountains (p. 153). Perhaps repeated in Greylock mountain, on the east of the Sparry limestone.
2. Sparry limestone.
1. Taconic slate, at the western base of the Taconic range, adjacent to the Hudson River shales.

The order of superposition, however, is not regarded as settled (p. 150).[†]

This is what Dana calls Phase I.

It is difficult to appreciate the reasons given by Dr. Emmons for placing his Taconic slate at the bottom (supposing this is what he means)—even in the light of his own section from Adams, Massachusetts, westward to the Champlain rocks of New York (given on p. 145). It is true the beds have a general dip eastward, giving the "Taconic slate" the appearance of dipping under all the other members; but the "Taconic slate" lies contiguous to the Champlain rocks, and even extends under them, though apparently by an overslip of the latter.

It is a singular inconsistency of Dr. Emmons, that in explaining the distinctions of the four limestones from the Primary to the Champlain, he expressly ranges the "Sparry limestone" above the "Stockbridge limestone" (p. 142)—an order which he was destined later to accept for the whole Taconic series. Similarly, (p.

---

[*] "Dividing the rocks into two classes, the primary and sedimentary" (p. 290) he says, elsewhere. See also p. 416.

[†] There are some indications that the order intended by Emmons is the reverse of this. So Mr. Marcou has understood him, in "The Taconic system and its position in stratigraphic geology" (*Proc. Amer. Acad.*, xii, 174-256. 1885.)

142) he places the "magnesian slates" below the "fine aluminous slate ("Taconic slate,") an order which he immediately, but with apparent unconsciousness, reverses (p. 144) and, though somewhat hesitatingly, defends (p. 147).

The Stockbridge limestone must be distinguished from the Primary limestone below, and the Sparry limestone must not be confounded with a silicious limestone occurring in the "Champlain group" above. Similarly, "the "Magnesian slate" must be distinguished from the lower Talcose slate of the Primary, and the Taconic slate must not be confounded with the shales and slates of the Hudson river. The Taconic rocks are entirely destitute of fossils; but "they furnish us with a knowledge of that state which immediately preceded the existence of organic beings" (p. 164). They are regarded as "equivalent to the Lower Cambrian of Professor Sedgwick," "the upper portion being the lower part of the Silurian system."

In the "Tabular Views" of the sedimentary rocks of New York (p. 429), the members of the Taconic system are given as follows:

4. Granular Quartz [=Potsdam sandstone.]
3. Stockbridge Limestone [=Blue limestone of Hudson Valley.]
2. Magnesian Slate [=Slates of the lowest formation of the Appalachian System.]
1. Taconic Slate.

I have placed at the right in brackets the equivalences of the Taconic members as maintained by professor H. D. Rogers, in 1844.[*]

It will be noticed that the relative positions of the Granular Quartz and Stockbridge limestone here are the reverse of those given near the commencement of this report. Also, the Sparry limestone is omitted.

1844. Dr. Emmons issued a thin quarto volume entitled "Taconic System," and dated December 2, 1844, containing the results of the previous two years of study. The Taconic system appears with important changes and an extension of area. The contents of the memoir were exactly reproduced (except the Preface) in his Report on the Agriculture of New York.[†]

1846. In the first volume of his Report on the Agriculture of New York,[‡] he devotes the fifth chapter (68 pages) to a fresh discussion of the Taconic system. Stimulated by the opinion of the brothers Rogers, accepted by Mather, E. Hitchcock and Dr. Samuel L. Dana, that the Taconic rocks were merely metamorphic conditions of the lower members of the New York or Appalachian system, he resumes, with new facts, a presentation of evidences sustaining his former positions, 1st, that the Taconic rocks are "inferior to the Champlain division of the New York system, or the lower division of the Silurian system of Murchison (p. 55); 2d, That they are a series of sediments reposing directly on the Primary system; 3d, That they contain previously unknown organic remains; 4th, That the lithologic members of the Taconic system have a different order of arrangement from that found within the New York system, and are much thicker than those to which they have been supposed equivalent in that system. The members of the system, as now recognized, are as follows:

---

[*] In May, 1844, Prof. H. D. Rogers returned to a discussion of the Taconic system, in his presidential address before the Association of American Geologists and Naturalists at Washington (*Amer. Jour. Sci.*, xlvii, 137, 247, 444). He seems to. have been the first to suggest that the Potsdam sandstone might not be the absolute base of fossilization among American rocks.

[†] *The Taconic System, based on observations in New York, Massachusetts, Maine, Vermont and Rhode Island.*

[‡] *Agriculture of New York*, vol. 1, 1746. p. 55.

6. Black slate (hitherto included in Taconic slate), with *Atops trilineatus* and *Elliptocephalus asaphoides*. I.
5. Taconic slate (with seven subdivisions), including Hoosick roofing slates with *Bucoides* and *Nereites*. III.
4. Sparry limestone (of Eaton). II.
3. Magnesian slate of Taconic and Saddle mountains.
2. Stockbridge limestone, in the Hoosick and Housatonic valleys, and extending to Sing Sing.
1. Brown sandstone or Granular Quartz, with four subdivisions.

This is what Dana calls Phase II.

The Sparry limestone is here replaced, the Black slate is separated from the Taconic slate, and the whole series is turned upside down. This order is now in accordance with the indications of the section given on page 145 of his Report on the Second District, and conforms with the theory of an overturn, as maintained by H. D. Rogers.

In this volume, the Taconic is recognized in Rhode Island, in Maine and in Michigan.

In another publication of about the same date* he makes a historical remark on the origin of the Taconic system, referring to the article in Disturnell's State Register. "In making up our notes for this object," he says, "we found it necessary to fix upon some general subdivisions of the rocks belonging to the State. We drew up an abstract of the plan, and submitted it to the criticism of the Rev. Prof. Dewey, of Rochester. . . . Professor

---

***American Quarterly Journal of Agriculture and Science*, vol. iv, 1846, p. 202.

Dewey approved of the division proposed, in the main. It resulted in separating the rocks in the vicinity of the Taconic range, both from the Primary and the New York Transition, as we then called them.

1848. Professor James Hall having described* *Atops trilineatus* of Emmons under the name of *Calymene beckii*, and referred it to the Hudson River group, and having also described in the same work (p. 256) *Elliptocephalus asaphoides* under the name of *Olenus asaphoides*, and referred it likewise to the Hudson River group (see especially Hall's foot-note, p. 257) professor Emmons, "with other specimens more perfect" presented to the American Association, a new and detailed description of *Atops trilineatus*, and a parallel description of *Triarthrus* (*Calymene*) *beckii*† pointing out what appeared to be important differences‡. He also discussed *Elliptocephalus*, and indicated technical distinctions between that genus and *Olenus* and *Paradoxides* (p. 18). In the same connection he repeated that the tenability of the Taconic system rested on structural and mineralogical evidence "far more important than the presence or absence of certain fossils"—meaning evidently, these fossils.

1855. In his "American Geology," the second part of which appeared this year,|| the Taconic system receives a new presentation. The following is a synopsis of the System as then understood:

Upper Taconic.	Black slate of Bald mouniain,	I. Cambrian.
	Taconic slate,	III. I. Hudson slates and Cam.
Lower Taconic.	Magnesian slate,	III. Hudson slates.
	Stockbridge L. includ'g Sparry L.	II. Lower Silurian.
	Granular Quartz.	I. Cambrian.

(I have added on the right, the equivalences as laid down in 1888, by professor J. D. Dana).

This is styled by professor Dana, Phase III; but the only change made since Dr. Emmons' last publication is the omission of the "Sparry Limestone," as in the "Tabular View," at the end of his Report on the Second District—this being merged in the "Stockbridge Limestone,"—and the recognition of a division of the system between the fossiliferous and the unfossiliferous portions—giving us "Upper" and "Lower" Taconic. There were two reasons

---

* *Paleontology of New York*, vol. i. p. 252., pl, lxv, figs, 4a-e.

† *Proc. Amer. Assoc.*, 1848, pp. 16-19.

‡ In his judgment of lack of identity, he had been sustained by S. S. Haldeman, chairman of a committee of the Association of American Geologists and Naturalists, a pointed to consider the question (*Amer. Jour. Sci.* II. v. 117, 1848). This judgment fessor Hall opposed (*Amer. Jour. Sci.* II, v. 322, 1848.)

|| *American Geology*, Part II, 830 pp., Albany, 1855, pp. 1-122.

for inverting the order as originally given: 1st, evidence of an overturn, as all along argued by Rogers, and as shown by the diagram given by Emmons himself; 2d, the discovery of fossils in the Black slate, which Emmons had always merged in the Taconic slate, or had closely associated with it (*Ag. Rep.*, *63*). Thus the Black and Taconic slates now stood at the top, but their close chronological association was an erroneous assumption—the former only belonging truly to the sub-Potsdam series. As Dr. Emmons excluded the Potsdam sandstone from the Taconic, and as the Granular Quartz has proved to be Potsdam sandstone, the Black slate was all that he had thus far really brought into the sub-Potsdam Taconic. This Black slate of Bald mountain, Rensselær county, was now the only imperishable nucleus of the Taconic system as conceived—however Dr. Emmons believed. The so-called Lower Taconic was pronounced azoic.

The following points taken from the "American Geology" (p. 122) embody the most important features of the system as then understood by its author: 1. "Its series divided into groups are physically unlike the Lower Silurian series; 2. "It supports unconformably at numerous places, the Lower Silurian rocks." 3. "It is a vital system, having been deposited during the period when organisms existed"; 6. It "carries us back many stages further in time, when life gave vitality to its waters, than the Silurian." To the Bald mountain locality of trilobites he here added one in Augusta county, Virginia, from which he described *Microdiscus quadricostatus*. He also described four marine plants, 22 graptolites and six molluscs.

Keeping in mind the black slate of Bald mountain, which had yielded two species of trilobites regarded by Emmons as sub-Potsdam in age, though described by Hall as of Hudson River age, it is interesting to note the discovery, about this time, of other trilobites in the Black slates of West Georgia, Vermont, lying within the region claimed by Emmons as Taconic. These falling, after two years, into the hands of professor Hall, were also described by him[*] as belonging to the Hudson River group. By this authority the beds were thus made equivalent to the Bald mountain Black slate. The names given these trilobites were *Olenus thompsoni*, *O, vermontana* and *Peltura holopyga*, now determined by Walcott as *Olenellus thompsoni* Hall, *O.* (*Mesonacis*) *vermontana* Hall sp. and *Bathynotus holopyga* Hall (*Amer. Jour. Sci.* III, xxxvii, 389, May, 1889). These were new accessions to the real

---

[*] *Twelfth Ann. Rep. New York Regents*, 1859, 50-62. On the age of the rocks see *Pal. N. York*, vol. III, p. 94; compare also *id.*, p. 83.

Taconic, for, though made Silurian by Hall, they were recognized by Barrande as primordial or sub-Silurian types. A real sub-Potsdam Taconic existed, therefore, in 1854, in Rensselaer county, New York, and in West Georgia, Vermont, not to mention Augusta county, Virginia. That fact was embraced in Dr. Emmons' claim.*

1859. We have no documents of this date from the pen of Dr. Emmons, showing his use of these primordial trilobites as vouchers for the existence of a real Taconic system. We find no recorded views from him on the publication made by Prof. Hall in 1859; but in his Manual of Geology† (p. 88) the preface of which is dated May 1, 1859, a large trilobite is figured under the name of *Paradoxides brachycephalus*, which, as suggested by professor C. H. Hitchcock in 1881,‡ is identical with *Olenus thompsoni* Hall.

This publication antedates that of the *Twelfth Regents' Report*. The evidence is, therefore, that independently of work done by others in Vermont, and before their results were published, Dr. Emmons had become acquainted with, delineated and published sub-Silurian trilobites within the Vermont area over which he had extended his asserted sub-Potsdam Taconic system. The Georgia slates now beginning to yield the palaeontological evidence of their age, were part of the "Primitive argillaceous slate" of professor Dewey;§ the "Primitive argillaceous slate" of Dr. E. Hitchcock;** the "Black slate" and "Taconic slate" of Dr. Emmons in various publications on the Taconic system.

1860. However, in a note at the end of the second edition of his Manual of Geology (p. 280) he says: "The slates or shales referred to (in the *Regents' Report* for 1859) in northern Vermont, as constituting a new series above the so-called Hudson River group, instead of ranking thus high in the geological scale, are really sub-Silurian, as is fully proved by the overlying calciferous sandstone.

---

*The Taconic system was maintained in the *Report on the Geological Survey of North Carolina*, 8 vo. 1856, pp. 49-72—reviewed in *Amer. Jour. Sci.* II, xxiv, 427-430.

†*Manual of Geology*. By E. Emmons. 290 pp. 8 vo. Philadelphia. 1860.

‡*Geology of Vermont*, vol. 1, 367.

‖According to Prof. Hall, the whole of the XIIth *Regents' Report* was published previous to Sept. 20, 1859. Mr. Billings gives Oct. or Nov. for the date of publication (*Canadian Naturalist*, vi, 316) though the date on the title page is March 15, 1859—evidently the date at which the printing began. This document purports to be "some of the results of investigations made during the years 1855, '56, '57 and '58 by James Hall" and a note states that they "are already printed in the third volume of the *Palaeontology of New York*." The transmission of this volume to the governor, nevertheless, is dated September, 1859," showing that though "printed," it was not published earlier than the *Twelfth Regents' Report*.

§*Geological Map of Berkshire, Mass.; Columbia and Rensselaer counties*, N. Y., Amer. Jour. Sci., viii, 124.

**Geological *Report of Massachusetts*, 1832.

. . . We now know the following trilobites, all of which belong to a slate beneath the Calciferous, viz: *Atops punctatus*, *Elliptocephalus* (*Paradoxides*) *asaphoides*, *Paradoxides Thompsoni*, *P. Vermontanus*, *P. macrocephalus*, *P.* (*Pagurus*) *quadrispinosus* and *Microdiscus quadricostatus*."

This extension and validity were given the Taconic system during the life of Dr. Emmons, and almost wholly through the persistence, ability, and force of his own efforts. The geologists of the country, save Vanuxem, Jewett and Billings, were unitedly against him. The most prominent palæontologist of the country had referred the Georgia trilobites to the upper part of the Hudson River group. The distinguished structural geologist of Canada, Sir William Logan, had rendered his testimony that the shales affording the fossils were "part of a series of strata which he is (was) inclined to rank as a distinct group above the Hudson River proper.[*] Only one authoritative voice was raised in vindication of Dr. Emmons' long contested claims. That voice came from across the ocean, and almost in tones of reproach for American palæontology, in failing to recognize the principles of order which it had professed to recognize in the succession of organic life, gave utterance to the sentiment: "Si le Dr. Emmons fait encore de la géologie c'est pour lui une belle occasion pour réproduire ses anciennes observations et ses idées avec plus de succés q'en 1844.[†]

No public documents relating to the Taconic, of later date than 1860, issued from the pen of Dr. Emmons. He went to North Carolina in September, 1860, as State Geologist, and remained within the Confederate lines during the civil war, "until he died, in 1863, at his plantation in Brunswick county, on the first of October". Mr. Marcou, however, maintained a correspondence with him until January 28, 1861, and from these letters I quote a few passages.[‖]

In a note dated Raleigh, Nov. 10, 1860, he says: "I do not think him (Barrande) right in maintaining that his Primordial Group is a part or parcel of the Silurian . . . The Lower Silurian is strictly unconformable to every part of my Taconic series." Writing the next day, he continues: "Perhaps I did Barrande injustice. . . I find that after all, his Primordial Group is only Lower Silurian. I conceive we have exactly his Primordial Group in the band of slates containing the *Paradoxides*.[*] On the 28th of December, referring to a communication rejected by the editor of the *American Journal of Science*, in which were embodied some comments on the Huronian system of Logan, he says : "I claimed that the Huronian was only the Taconic system." On January 23, 1861, he writes : "It was ten years ago, I think, when I claimed Logan's Huronian system as nothing more than the Taconic. . . The acknowledgment of the Primordial of Barrande in this country (referring to some concessions of Sir William Logan)[†] is really one of the finest and best facts in geology, making a co-ordination of American and European rocks so complete and harmonious ; I think of nothing I have said or done in this matter ; I look upon the harmony of the systems ; they are truly worth dwelling upon."

---

[*] Twelfth Report N. Y. Regents, p. 62, note.

[†] Letter of M. Barrande to M. Marcou, 14th Aug., 1860, (*Proc. Amer. Acad.*, 1885. p. 182) "On the Primordial Fauna and the Taconic System of Emmons." Also, in part, *Proc. Boston Society Nat. Hist.* vii, Dec. 1860, 369-375.

[‖] The letters are published, with much other correspondence, in *Proc. Amer. Acad.*, xii, 1885, pp. 181-224.

In reference to M. Marcou's proposal to include the Potsdam sandstone within the Taconic, Dr. Emmons writes, January 28, 1861 : "Let me declare once for all, that I have not the slightest objection to your view. . . If you believe you can make out a good case with the Potsdam anywhere, I never shall object, for I have no wants except truth."

These noble sentiments close the correspondence, and constitute, so far as I know, the last utterance of Dr. Emmons which passed the lines of a country so soon to become the theatre of bloody war.

Let us now consider the form which the Taconic system had assumed during the lifetime of its author :

Upper Taconic.	Potsdam sandstone (suggested by Marcou, assented to by Emmons).	I. Cambrian.
	Black slate of Bald Mountain and Georgia slates of Vermont.	I. Cambrian.
	Taconic slates.	III. Hudson slates and I. Cam.
Lower Taconic.	Magnesian slate.	III. Hudson slate.
	Stockbridge limestone, including Sparry limestone.	II. Lower Silurian.
	Granular quartz.	I. Cambrian.

---

[*] This looks like an admission that Emmons' *Paradoxides* band was Lower Silurian—against which he contended. But though Primordial was Silurian in the extended sense in which Barrande used the term, it was beneath the Silurian as Emmons conceived it. On the previous day he had declared Barrande's Primordial *not* properly Silurian.

[†] About this time, in a letter to Barrande, dated Dec. 31, 1860, Sir W. E. Logan wrote: "Professor Emmons has long maintained . . . that rocks in Vermont which in June, 1859, I for the first time saw and recognized as equivalent to the magnesian part of the Quebec group, are older than the Birdseye limestone ; the fossils which have this year been obtained at Quebec, pretty clearly demonstrate that in this he is right. It is at the same time satisfactory to find that the view which Mr. Billings expressed to you in his letter of the 12th. July, to the effect that the Quebec trilobites appeared to him to be about the base of the second fauna, should so well accord with your own opinions, and that what we were last spring disposed to regard at Georgia as a colony in the second fauna should so soon be proved, by the discoveries at Quebec, to be a constituent part of the Primordial Zone." This, says Barrande (*Documens anciens et nouveaux*, etc. *Bull.* 4 Fev., 1869, p. 320) "is a formal recognition by Sir William Logan, of the Taconic System at the base of the Silurian."

On the right are the parallelisms established by Dana, Walcott and others. The Table shows the Taconic system left by its author in state of incompleteness—even confusion. We find three members whose true positions are above the Potsdam sandstone. But we find also three members whose positions are admitted to be sub-Potsdam—as maintained by Emmons. The mal-position of the Stockbridge limestone was an error of exactly the same magnitude as that of the geologists who would identify the Granular quartz with the Potsdam sandstone, or would make the Black slates of Georgia synchronous with the Hudson River shales. Our science was then in a comparatively crude state, and none of these errors need surprise us. We have ascertained that a real sub-Silurian system exists, and that Dr. Emmons fixed upon three if not four of its members. Such are the facts. Geologists will differ as to the question whether such a degree of success entitles Dr. Emmons to a recognition of the name proposed by him for the real system whose existence he mentally apprehended so well, but whose form he defined so imperfectly.

It is intended to pursue the later history of opinion concerning the Taconic system, as, with the progress of science, the question became more and more palæontological; and if not yet regarded as settled, the discussion is proceeding mainly on palæontological grounds. [*] The principal papers published in the controversy, since the close of the era of the founder—about 1860, will, unless previously quoted, be found cited in the subjoined note.

---

[*] 1860. Barrande, Joachim.
On the Primordial Fauna and the Taconic system, with Notes by Jules Marcou. *Proc. Bos. Soc. Nat. Hist.*, Vol. VII, pp. 369–382.
1861. Barrande, J.
Documens anciens et nouveaux sur la faune primordial et le système Taconique en Amérique. Paris, 1861.
1861. Hunt, T. S.
On the Taconic system of Emmons. *Amer. Jour. Sci.* II. xxxii, 427–430.
1861. Hunt, T. S.
On some Points in American Geology. *Amer. Jour. Sci.* II, xxxi, pp. 392-414.
1861. Marcou, Jules.
The Taconic and Lower Silurian Rocks of Vermont and Canada. *Proc. Bos Soc. Nat. Hist.*, Vol. viii, pp. 239-253.
1862. Marcou, Jules
Liste additionelle des fossiles du terrain Taconique de l'Amérique du Nord. *Bull. Soc. géolog. de France*, vol. xix p. 746 Paris.
1862. Marcou, Jules
Letter to Mr. Joachim Barrande on the Taconic Rocks of Vermont and Canada, Aug. 1862, pp. 1-15, Cambridge, Mass.
1863. Bigsby, J. J.
On the Cambrian and Huronian Formations. *Quar. Jour. Geol. Soc.*, 36-52, Feb. 1863.
1864. Marcou, Jules
Notice sur les gisements des lentilles trilobitifères taconiques de le Poi nte Lévis au Canada. *Bull Soc. géol. de France*, vol. xxi, pp. 236-250 (Paris.)
1865. Logan, W. E.

On the Geology of Eastern New York [Tour with James Hall.] *Canad. Naturalist and Geol.* . Republished, *Amer. Jour. Sci.*, II, xxxix, 96-98.

1869. Perry, J. B.

A point in the Geology of Western Vermont. *Amer. Jour. Sci.* II, xlvii, 341-349 [Important].

Brainerd and Seely,

The Marble Border of Western New England. *Middlebury Historical Society*. Vol. 1, Pt. II, 1885.

Julien, A. A.

On geology at Great Barrington, Mass. *Trans. N. Y. Acad. Sci.* 1887.

1873. Dana, James D.

On the Quartzite, Limestone and associated Rocks of the Vicinity of Great Barrington, Berkshire county, Mass. . *Amer. Jour. Sci.*, III, iv. pp. 362-377; 450-453; v. pp. 47-53; 84-91; vi, pp. 257-278.

1877. Dana, James D.

An Account of the Discoveries in Vermont Geology of the Rev. Augustus Wing. *Amer. Jour. Sci.* III, xii, pp. 332-347; 405-419; xiv, pp. 36-7.

1877. Dana, James D.

On the Relations of the Geology of Vermont to that of Berkshire. *Amer. Jour. Sci.* III., xiv, pp. 37-48; 132-140; 202-207; 257-264.

1878. Prime, Frederick, Jr.

On the Discovery of Lower Silurian Fossils in Limestone associated with Hydromica Slates, and on other Points in the Geology of Lehigh and Northampton counties, Penn. . *Amer. Jour. Sci.* III, xv, 261-269.

1879. Dale, T. Nelson, Jr.

On the Age of the Clay-slate and Grits of Poughkeepsie. *Amer. Jour. Sci.* III. xvii. 57-59.

1879. Dana, J. D.

On the Hudson River Age of the Taconic Schists, and on the dependent Relations of the Dutchess county and Western Conn. Limestone Belts. *Amer. Jour. Sci.* III, xvii, 375-388; xviii, 61-64.

1879. Dwight, W. B.

On some Recent Explorations in the Wappinger Valley Limestone of Dutchess county, N. Y., *Amer. Jour. Sci.* III, xvii, 389-393.

1879. Whitfield, R. P.

Discovery of Specimens of *Maclurea magna* of the Chazy, in the Barnegat Limestone near Newburgh, N. Y., *Amer. Jour. Sci.* III, xviii, 227.

1880. Lesley, J. P.

A Hudson River Fossil Plant in the Roofing Slate that is associated with chlorite Slate and Metamorphic Limestone, in Maryland, adjoining York and Lancaster counties, Pa., *Proc. Amer. Philosoph. Soc.*, xviii, 365; *Amer. Jour. Sci.* III, xix, 71-2.

1880. Ford, S. W.

Note on the Trilobite, *Atops trilineatus* of Emmons [Holding it distinct]. *Amer. Jour. Sci.*, III, xix, 152-3.

1880. Dana, J. D.

List of Papers on the Taconic System [as at first defined by Emmons] [with statements of points]. *Amer. Jour. Sci.*, III, xix, 153-154.

1880. Ford, S. W.

On the Western Limits of the Taconic System. *Amer. Jour. Sci.*, III. xix, 225-226.

1881. Winchell, N. H.

The Potsdam Sandstone. [Discusses Taconic]. *VIIIth Ann. Rep. Minn.* pp. 123-136.

1881. Dana, J. D.

Geological Relation of the Limestone Belts of Westchester County, N. Y., *Amer. Jour. Sci.*, III, xxii. 313-315-327-335.

1881. Marcou, J.

Taconic Rocks of the Border of Lake Champlain. *Bull. Soc. géol. France*, Nov., 1880. Noticed *Amer. Jour. Sci.*, III, xxii, 321-2.

1882. Dana, J. D.

Geological Age of the Taconic System. *Quar. Jour. Geol. Soc. Lond.*, xxxviii, 397, Abstract *Amer. Jour. Sci.*, III, xxiv, 291-3.

1883. Hunt. T. S.

The Taconic Question in Geology. *Trans. Roy. Soc. Canada*, Vol. I, Sec. 4. [Dana says "Deficient and one-sided."]

1883. Selwyn, A. R. C.
Notes on the Geology of the Southeastern Portion of the Province of Quebec. *Can. Rep.* for 1880-1-2, A. pp. 6-7.

1883. Walcott, C. D.
The Cambrian System in the United States and Canada, *Bull. Philosoph. Soc.*, Washington, vol. vi, pp. 98-102.

1884. Walcott, C. D.
On the Cambrian Fauna of North America. *Bull. U. S. Geol. Surv.*, No. 10, pp. 55 and nine plates.

1884. Winchell, N. H.
[Incidental discussion of Taconic in] The Crystalline Rocks of the Northwest. *Proc. Amer. Assoc.*, 1884, pp. 363-379.

1884. Ford, S. W.
On the Age of the Glazed and Contorted Slaty Rocks in the vicinity of Schodack Landing. *Amer. Jour. Sci.*, III, xxviii, 206-208. Erratum, p. 242.

1884. Dana, J. D.
On the Southward Ending of a Great Synclinal in the Taconic Range. (Read before the British Association). *Amer. Jour. Sci.* III, xxviii, 268-275.

1884. Hall, James.
On the Hudson River Age of the Taconic Slates. [Notice of by Dana]. *Amer. Jour. Sci.*, III, xxviii, 811-312.

1885. Marcou, Jules.
The "Taconic system," and its Position in Stratigraphic Geology. *Proc. Amer. Acad. of Arts and Sciences*, Vol. xii, 174-256. [With bibliographical statements and letters from Emmons and Barrande.]

1885-7. Dana, J. D.
On Taconic Rocks and Stratigraphy, with a Geological map of the Taconic region. *Amer. Jour. Sci.* III, xxix, 205-222; 437-443; xxxiii, 270-276; 393-412.

1886. Dana, J. D.
On Lower Silurian Fossils from a Limestone of the original Taconic of Emmons. [Amer. Assoc., 1885], *Amer. Jour. Sci.* III, xxxi, 241-248.

1886. Ford, S. W. and W. B. Dwight.
Preliminary report upon Fossils obtained in 1885, from metamorphic limestones, of the Taconic series of Emmons, at Canaan, N. Y., *Amer. Jour. Sci.* III, xxxi, 248-255, with plate vii.

1886. Dana, J. D.
The History of Taconic investigation previous to the work of Professor Emmons, (Address, Berkshire Historical Soc., Feb. 1885.) *Amer. Jour. Sci.* III, xxxi 399-401.

1886. Walcott, C. D.
Classification of the Cambrian system of North America (Read before National Academy of Science, Washington, Apr. 23, 1886) *Amer. Jour. Sci.* III, xxxii, 138-157.

1886. Walcott, C. D.
Second Contribution to the Cambrian Faunas of North America, 369 pp. 8vo. with 33 plates. *Bull.* No. 30. *U. S. Geol. Surv.*

1886. Hunt, T. S.
Mineral Physiology and Physiography [Taconian (Taconic) considered extensively in many parts of the work. See Index.]

1887. Winchell, N. H.
Notes on Classification and Nomenclature for the American Committee of the International Geological Congress. *American Naturalist*, March, 1887, p 693-700.

1887. Hunt, T. S.
The Taconic Question Restated. *Amer. Naturalist*, xxi, 114-125; 238-250; 312-320.

1887. Dwight, W. B.
Palæontological Observations on the Taconic Limestone of Canaan, Columbia county, N. Y. (Amer. Assoc. Aug., 1886,) *Amer. Naturalist*, 1887, p. 270.

1887. Walcott, C. D.
Geologic Age of the Lowest Formations of Emmons' Taconic System. Read before Philosophical Soc. Washington, Jan. 15, 1887. Abstract, *Amer. Jour. Sci.*, III, xxxiii, 153-4.

1887. Dana, J. D.
The Views of Professor Emmons on the Taconic Question. *Amer. Jour. Sci.*, III, xxxiii, 412-419.

1887. Walcott, C. D.
Fauna of the "Upper Taconic" of Emmons, in Washington county. N. Y., *Amer. Jour. Sci.*, III, xxxiv, 187-199.

1887. Irving, R. D.
Is there a Huronian Group? *Amer. Jour. Sci.*, III, xxxiv, 204-216; 246-263; 365-374.

1888. Bonney, T. G.
Notes on the part of the Huronian Series, in the neighborhood of Sudbury Canada. *Quar. Jour. Geol. Soc.* London, Feb. 1888, pp. 32-35.

1888. Marcou, Jules.
American Geological Classification and Nomenclature. pp, 75 Cambridge.

1888. Marcou, Jules.
On some Dates of the "Report on the Geology of Vermont." *Proc. Boston Soc. Nat. Hist.*, vol. xxiii, 83-89.

1888. Hitchcock, C. H.
Date of the Publication of the Report upon the Geology of Vermont. *Proc. Boston Soc. Nat. Hist.*, xxiv, 32-37.

1888. Winchell, N. H.
Some Objections to the Term Taconic Considered. *Amer. Geologist*, i, 162-172. March.

1888. Winchell, N. H.
Note in Reply to Walcott. *Amer. Geologist*, i, 220-224.

1888. Miller, S. A.
The Taconic System as established by Emmons, and the Laws of Nomenclature applicable to the Subject. *Amer. Geol.* i, 235-245.

1888. Winchell, Alexander.
The Taconic Question. *Amer. Geologist*, i, 347-363, June.

1888. Marcou, Jules.
Palæontologic and Stratigraphic "Principles" of the Adversaries of the Taconic. *Amer Geologist*, ii, 10-23; 67-88, July and Aug.

1888. Selwyn, A. R. C.
Huronian, Taconic and Quebec. *Amer. Geologist*, ii, 61-62, 135.

1888. Winchell, N. H.
[Use of the term Taconic, in Report to International Committee] *Amer. Geologist*, ii, 208-211.

1888. Walcott, C. D.
On the Taconic System of Emmons [Compiled as an expression of opinion] *Amer. Geologist*, ii, 215-219, with Note by N. H. Winchell, 220-224.

1888. Vogdes, A. W.
Some Forgotten Taconic Literature. *Amer. Geologist*, ii, 352-355.

1888. Walcott, Charles D.
The Taconic System of Emmons, and the Name Taconic in Geologic Nomenclature. *Amer Jour. Sci.* III, xxxv, 229-242; 307-327; 394-401.

1888. Dana, James D.
A brief History of Taconic Ideas. *Amer. Jour. Sci.* III, xxxvi, 410-427.

1889. Marcou, Jules.
Canadian Geological Classification for the Province of Quebec. *Proc. Boston Soc. Nat. Hist.*, xxxiv, 54-83.

1889. Marcou, Jules.
Barrande and the Taconic System. *Amer. Geologist*, iii, 118-137.

1889. Marcou, Jules.
The Taconic in the Salt Range of the Punjab (India). *Amer. Geologist*, iv, 60-62.

1889. Howley, James P.
The Taconic of Eastern New Foundland. *Amer. Geologist*, iv, 121-125.

1889. Walcott, C. D.
Stratigraphical position of the *Olenellus* Fauna in North America and Europe. *Amer. Jour. Sci.*, III, xxxvii, 374-392; xxxviii, 29-42.

1889. Dwight, W. B.
Recent Explorations in the Wappinger Valley Limestone, No. 7. In the Millerton-Fishkill Limestone Belt; also in a Belt near Rhinebeck. *Amer. Jour. Sci.*, III, xxxviii, 139-153.

1890. Dwight, W. B.
Fossils of the western Taconic Limestone, in the eastern part of Dutchess county, N. Y. (Announcement.) *Amer. Jour. Sci.*, III, xxxix, 71.

DOUGLASS HOUGHTON.

1831. Dr. Houghton's earliest record in respect to the rocks of Michigan is found in his report to the Secretary of War as Botanist of Schoolcraft's Expedition.* Speaking of the copper of lake Superior, he says: "After having duly considered the facts which are here presented, I would not hesitate to offer as an opinion that the trap rock formation was the original source of the masses of copper which have been observed in the country bordering on Lake Superior; and that at the present day, examinations for the ores of copper could not be made in that country with hopes of success, except in the trap rock itself; which rock is not certainly known to exist in any place upon lake Superior other than Kewena point." This opinion on the source of the native copper he had subsequently abundant opportunity to confirm, though opposed by much scientific incredulity.

1840. In his Third Annual Report on the geology of Michigan, dated February 3, 1840, summarizing observations of 1839, Dr. Houghton treats of the "Upper Peninsula." Under the head of "General Geology of the South and Southeasterly Part of the Upper Peninsula," † after describing the distribution of the "Primary rocks" in Michigan, he says: "The immense Primary region of which the line described may be considered as it were, a single point, stretches nearly continuously, many hundred miles northwesterly, skirting a portion of the shores of lake Superior, and in conjunction with the trap rocks, constituting the highlands between that lake and lake of the Woods. From these highlands it stretches a little east of lake Winnipeg, far to the northwest, finally constituting the immense "barren grounds" of the British Possessions. It is also well known that this range of primary rocks stretches in an easterly direction through the interior of the upper province of Canada" (p. 11).

This is the earliest general location of the eastern nucleus of the continent.

1890. Marcou. J.
The Lower and Middle Taconic of Europe and North America. *Amer. Geologist*, v. 357-373; vi, 78-102, 222-233.
1890. Winchell, N. H. and H. V. Winchell.
The Taconic Ores of Minnesota and Western New England. Read before the Geological Society of America, Aug. 19. *Amer. Geol.* Nov. 1890.
1890. Winchell, N. H.
What Constitutes the Taconic Mountains? Read before Sec. E, Amer. Assoc. Adv. Sci., Aug. 22, 1890. *Amer. Geol.*, vi, 247.

*Nov. 14, 1831. Also Henry R. Schoolcraft, *Discovery of the Source of the Mississippi* New York, 1834, pp. 287-292.

†*Senate Document* No. 8, 1840, p. 10.

Some further but disconnected quotations will be introduced.

"On the mainland at these 'narrows' [the place where the current of Ste. Marie's river meets the slack-water of lake Huron] and extending for several miles, the knobs are composed of compact greenstone, occasionally partaking of a sub-slaty character, and under which circumstances, the rock bears a close analogy to some of the varieties of primary argillite."

"On the northern part of the island of St. Joseph, a fraction of the southeastern part of Sugar island, and a portion of the main land on the east, the place of the hornblende rock is supplied by granular quartz rock, usually white, but sometimes passing to a reddish or deep red color."

"In the range of hills bounding the easterly side of Great Lake George, talcose slate was observed, but to what extent it exists I am unable to say" (p. 13).*

It appears that Dr. Houghton's conception of "Primary rocks" was rather broad. The granular quartz rock mentioned is now known to be a westward extension of the "Huronian" quartzites of the Thessalon valley in Canada. The "talcose slate" on the other hand, probably belongs to the Marquette iron-bearing series which by the present writer has been suggested to be an older system than the Huronian. It is worthy of note also, that Dr. Houghton reports the "Lake Superior sandstone" as resting "against and upon the Primary range of the Ste. Marie's river." That is, at one point the "talcose slates" (Marquette series) rest in contact with the gneisses ; at another, the overlying quartzyte (Huronian) extends over to the gneiss ; and at another, the still higher sandstone (Palæozoic) reaches over to the gneiss. Thus, it is unsafe to conclude that the formation resting on the gneiss at any particular spot is the one historically next in order of age.

1841. In his report for the following year, †he continues his description of the Northern Peninsula. His conception of Primary rocks appears more restricted, for he says they "are chiefly granite, syenite and syenite granites." (p. 15.) After describing the vast development of "Trap Rocks," he recognizes a group designated "Metamorphic Rocks." "Flanking the Primary rocks on the south," he says, "is a series of stratified rocks consisting of talcose, mica and clay slates, slaty hornblende rock and quartz rock; the latter rock constituting by far the largest proportion of the whole group." These represent the group of rocks in the Menominee region, which Dr. Emmons so eagerly accepted as representatives of the Taconic system in Michigan.

---

*In view of the recent extensive employment of "field stones" in some parts of the state, in the walls of substantial structures, the following quotation from this report possesses interest: "In the immediate vicinity of the surveyed line of the Ste. Marie's canal, transported masses of granite, hornblende, sienite and quartz rocks abound, and they may be economically employed for the construction of the proposed locks, and will make an enduring structure." (p. 15).

†Senate Document No. 16, 1841.

The following is an interesting early notice of the mode of occurrence of serpentine. "In traversing the country southeasterly from Little Presqu' ile, the point referred to as the most southeasterly prolongation of the granite, this last rock passes almost insensibly into a serpentine rock* which has a regular jointed structure, sometimes approaching to stratification; continuing in the same direction, we find a series of hornblende slates, talcose, mica and clay slates, resting against the serpentine rocks; and still farther to the southeast, the rock becomes almost uniformly quartz. The rocks of this group dip irregularly to the south and southeast, while the cleavage of the slate is very uniformly to the north," (p. 17.)

A gradual passage from granite to "greenstone" is noted as follows: "As we proceed northwesterly from the southeast boundary of the Primary, over the several broken ranges of hills, we find the character of the rocks in mass almost imperceptibly changing. The quartz as a mineral gradually forms a less important part, and it finally almost wholly disappears, leaving a binary compound of feldspar and hornblende, which then assumes a granular structure, constituting greenstone. The intermediate rock between the syenite and greenstone ranges may not inappropriately be called a syenitic greenstone," (p. 23.)

The granitic rocks are intersected by dikes which can be traced continuously and with increasing abundance, into the greenstone masses, showing the granitic ranges to be the oldest (p. 24).

In reference to amygdaloids he says: "I am disposed to refer the origin of much of the amygdaloid rock to the fusion of the lower portion of the sedimentary rocks referred to, for the reason that as we pass south from the junction [receding from the sedimentary rocks] the amygdaloid rocks wholly disappear, their places being supplied by greenstone; and again, so intimately are they blended that it is frequently impossible to determine where the amygdaloid ceases and the upper sedimentary rocks commence. Fragments of the sedimentary rocks, the characters of which can be clearly recognized, are not of rare occurrence, imbedded in the amygdaloid rock, a circumstance which, although by no

---

*The curious history of opinion concerning this much discussed rock is compiled by Dr. Wadsworth in *Bull. Mus. Comp. Zool.*, Geol. Series, I. pp. 60-65.

means conclusive, should not be overlooked in considering the subject" (pp. 27 and 28).

Of the conglomerate rock he says: "It may without doubt be considered as a trap tuff, which was gradually deposited or accumulated around the several conical knobs of trap during their gradual elevation" (p. 33). It is very variable in thickness. There is "scarcely a pebble of any other rock than trap." They are cemented by "a mixed calcareous and argillaceous cement more or less colored by iron, and exceedingly firm. The conglomerate is "imperfectly stratified in masses of immense thickness," in its maximum a little east of Montreal river, estimated at 5,260 feet, (pp. 34, 35).

The formation described as "mixed conglomerate and sandrock" "is made up of an alternating series of conglomerate and red sandstones which rest conformably on the conglomerate rock last described" and "in strictness should probably be considered as a member of the conglomerate itself" (p. 18). Its greatest observed thickness is 4,200 feet. The conglomerate beds resemble in all respects the underlying conglomerate, and the intervening sandstone beds are composed of the same materials, but are sometimes ripple marked, and were thus evidently deposited in shallow water. These sandstone beds are very distinct in composition from the "red" and "grey" sandstones higher in the series" (pp. 19, 37).[*]

It will serve to convey an idea of the extent of Dr. Houghton's researches in the Upper Peninsula to state that the *Exec., Doc.*, 1849-50, Part III, contains (p. 880), the following among Houghton's results: 1. "A Geological Map of the Townships of the Northern Peninsula of Michigan subdivided by D. Houghton, D. S. in the year 1845." (This covers Keweenaw Point.) 2. "Geological Map of Township Lines in the Northern Peninsula of Michigan, surveyed by Wm. A. Burt, D. S. in the year 1845, for D. Houghton, under said Houghton's contract for surveys with reference to Mines and Minerals" (The region on Little Bay de Noquet and along the Escanaba river and to lake Superior.) 3. "Geological Map of a District of Township Lines in the Northern Peninsula of Michigan, surveyed by Wm. A. Burt in the year 1846." (Region between the Escanaba and Menominee rivers.) Also (p. 896.) 1. "Geological Map of a District east and west of the Ontonagon, subdivided by Messrs. Higgins and Hubbard under a Contract bearing date April 23, 1846" (From Portage lake to Carp river.) 2. "Geological Map of the District subdivided by Messrs. Hubbard and Ives, under Contract bearing date September 7, 1846." (The Region from Presqu' ile to L' Anse.) These six maps were produced under the system of combined linear and geological surveys inaugurated by Dr. Houghton. Thus nearly the whole of the Upper Peninsula had been geologically mapped before the signing of the contract with Foster and Whitney, and without including the results of Dr. Jackson's survey. Mr. Hubbard gives also, five handsomely drawn sections from lake Superior, across the country southward, besides five lithographed views.

---

[*] The "red sandrock" associated with "shales" is much more quartzose than the beds intercalated with the conglomerate. It attains a maximum thickness of 6,500 feet. "On the southeast side of Keweenaw bay, near its head, an argillaceous rock appears" "evidently embraced in, or rather may be said to constitute a member of, the sandstone series." It is sometimes, "in the form of a slate," though usually it "closely resembles indurated clay." It can be cut with the knife, and the Indians have long used it as a pipestone. A similar rock appears at several other points in the interior. These slates are shown by his notes of 1845, to pass under the sandstone.] The "Upper, or Grey Sandrock" is no part of the Lake Superior sandstone. While the latter dips northeasterly, this dips southeasterly, and is conformable with the overlying limestones. The "Grey Sandrock" forms a range of hills extending westward from Pt. Iroquois to the Pictured Rocks, where they abut upon the shore of the lake. It is Dr. Houghton's opinion, therefore, that the Pictured Rocks are a higher formation than the Red Sandstone, generally contemplated as the "Lake Superior Sandstone" (19,42.) The Lake Superior sandstone Dr. Houghton was at first inclined to parallelize with the "Old Red Sandstone" (*Report*, 1838); but, in a paper read before the Association of American Geologists in 1843, he assumed it as identical with the "New Red Sandstone" (*Amer. Jour. Sci.*, xlv, 160.) Later he synchronized it with the Potsdam sandstone of New York, and this view was embodied in his notes of 1845 (*The Mineral Region of Lake Superior*, 1846, by Jacob Houghton.) The statement is contained in a report by Bela Hubbard—page 118—compiled from Dr. Houghton's notes;) Also, *Executive Docs.*, 1849-50, pt. III, p. 839. The same was noted on the plats of 1845. See also the testimony of Foster and Whitney, *Report on the Geology of the Lake Sup. Land Dist.*, Pt. II, p. 138, and *Proc. Amer. Assoc. Adv. Sci.* May, 1851, p. 23.

The following is Dr. Houghton's latest view of the succession of rocks in the Upper Peninsula of Michigan:

6. Upper or Gray Sandstone (Houghton, 1841, pp. 19, 41) not conformable with next below.

5. Lower or Red Sandstone and Shales (Houghton, 1841, pp. 18, 37). Identified with Potsdam Sandstone.

4. Mixed Conglomerate and sandstone (Houghton, 1841, pp. 18, 35).

3. Conglomerate (Houghton, 1841, pp. 17, 33).

2. Metamorphic rocks (Houghton, 1841, pp. 16, 31). Quartzite, Argillite, Talcose and Clay slates, Mica slate.

1. Primary rocks (Houghton, 1841, pp. 15, 23). Granite, Gneiss, Syenite and Syenitic Granite.

Numbers 6 and 5 are probably both representatives of the New York Potsdam. Numbers 4 and 3 are the Keweenawan System of Chamberlin and Irving, and number 2 occupies the place of the Taconic system of Emmons.

EDWARD HITCHCOCK.

1833. In his Final Report on the Geology of Massachusetts,* Professor Edward Hitchcock enumerates, among others, the following rocks or groups of rocks mineralogically considered: Graywacke, Argillaceous slate, Limestone, Scapolite rock, Quartz rock, Mica slate, Talcose slate, Serpentine, Hornblende slate, Gneiss — all which are stratified; Greenstone, Porphyry, Syenite and Granite — which are unstratified. Of the Berkshire limestone, he thinks a part is "primitive, in the Wernerian acceptation of the term, for it is interstratified with gneiss and mica slate" (p. 297). But the mica slate in its westward extension becomes clay slate, and the limestone less crystalline. Passing into New York, the limestone assumes the character of Dewey's "transition limestone."

"But a singular anomaly in the superposition of the series of rocks above described presents a great difficulty in the case. The strata of these rocks almost uniformly dip to the east; that is, the newer rocks seem to crop out beneath the older ones, so that the saccharine limestone associated with the gneiss in the eastern part of the range seems to occupy the uppermost place in the series. Now, as superposition is of more value in determining the relative ages of rocks than mineral characters, must we not conclude that the rocks as we go westerly from Hoosac mountain, do in fact, belong to older groups? The petrifactions which some of them contain, and their decidedly fragmentary [fragmental] character will not allow such a supposition to be indulged in for a moment. It is impossible for a geologist to mistake the evidence which he sees at almost every step, that he is passing from older formations, just as soon as he begins to cross the valley of Berkshire towards the west. We are driven then, to the alternative of supposing either that there must be a deception in the apparent outcrop of the newer rocks from beneath the older, or that the whole series of strata has been actually thrown over, so as to bring the newest rocks at the bottom. The latter supposition is so improbable that I cannot at present admit it" (pp. 297-298). He then supposes two unconformities to have been produced — one at the west base of Hoosac mountain between the gneiss and the quartz rock, and the other farther west, in the valley of Berkshire. He names some difficulties involved in the acceptance of such an explanation, but feels compelled to adopt it provisionally. Moreover, he says, "I am sustained in this opinion by that of Dr. Emmons of Williams College, whose acuteness of observation and accuracy of discrimina-

---

* Report on the Geology, Mineralogy and Botany and Zoology of Massachusetts. By Edward Hitchcock. Amherst, 1833, Roy. 8-vo, pp. 700.

[illegible] tale [illegible]

[illegible] ultimate [illegible]

[illegible] above referred [illegible]

[illegible] that serpentine [illegible]

[illegible] and since the [illegible]

[illegible] the latter must [illegible]

[illegible] found that serpentine [illegible]

[illegible] contained [illegible]

[illegible] enclosed in its [illegible]

[illegible] formed" (pp. [illegible]

[illegible] theoretical consi[illegible]

[illegible] composed [illegible] the same [illegible]

[illegible] natural to infer that both must have [illegible]

[illegible] are we led to such a conclusion, [illegible]

[illegible] a gradual passage from the one [illegible]

[illegible] resulted from heat instead of [illegible]

[illegible] so well established that the opin[illegible]

[illegible] no longer to be [illegible]

[illegible] At present [illegible]

[illegible]

n
ıy
ks.
into

---

ary Ad-

s at their
ol. xli, pp.

ed from the melting down of other rocks; the fused mass having cooled so slowly as to present a confused crystallization. It is at least, a probable supposition, that the rock out of which it was produced was of mechanical origin, and consequently stratified. Now, if the central heat was not sufficient entirely to melt this stratified rock, yet it would be powerfully affected a considerable distance upward from the molten mass. The first in immediate contact with the melted portion would be partially fused, and hence give origin to granitic gneiss. Another portion might be converted into porphyritic gneiss; another, into lamellar; another into schistose, etc. All the rock, we may suppose so near the fluid granite, and so long in contact with it, before cooling, that crystalline would succeed to a mechanical arrangement of all its ingredients, without losing the stratified disposition (p. 400).

In discussing the history of granite, professor Hitchcock states that he infers its igneous origin "from the inclined position of the older stratified rocks; from the manner in which it is intruded among the stratified rocks; from the mechanical effects which it appears to have exerted upon the stratified rocks in its immediate vicinity; from its chemical effects upon the surrounding strata, and from its crystalline structure, and the numerous crystallizations of other substances that have taken place in it" (pp. 509-515).

1840-1. The inversion of the strata of the Appalachian system is referred to again in his Elementary Geology.* Speaking of overturned strata in the Alps, he says:

"I have no small reason to believe that a similar folding and overturning of the strata have taken place on a vast scale in the United States. Along the western part of the Green and Hoosac mountains in New England, occur interstratified beds of gneiss, mica slate, talcose slate, clay slate, limestone and older Silurian rocks which are either perpendicular or have a high easterly dip; and yet the oldest members of the series are found along the eastern side of this belt, and the strata become newer and newer as we go westerly; that is, the oldest rocks lie apparently over the newer ones. These appearances present themselves nearly the whole distance from Connecticut river to Hudson river—a breadth of nearly fifty miles." He then describes the folding, overturn and denudation which would result in the present structure and surface aspects. "It appears further, from the Geological Reports of Professors Mather on New York, Henry D. Rogers on New Jersey and Pennsylvania, William B. Rogers on Virginia, and Troost on Tennessee, that these same

---

**Elementary Geology.* The Preface to the first edition is dated August 1, 1840; that of the third edition, April, 1842. I quote from the third, 12mo., pp. xii 352.

rocks with similar inversion of their dip, occur in all those states, forming a considerable part of the Appalachian mountains; and that in fact, they extend almost uninterruptedly from Canada to Alabama—a distance of nearly 1200 miles; and if the above theory of the folding and inversion of this belt of rocks be correct in the latitude of Massachusetts, it is without doubt, true over this vast extent of country."*

The subject of inverted arrangement of the Appalachian strata was under careful consideration at this time, by the brothers Rogers, as well as by Dr. Hitchcock. The earliest enunciation of the conception of an inverted fold had been made by Dr. Hitchcock in 1833. His conception however, was not identical with that of the brothers Rogers. He spoke only of a single anticlinal, while the Rogers brothers saw a succession of anticlinals all tilted westward across the main mass of the Appalachians. In an address delivered in 1841, he said:†

"There is no small reason to believe, indeed, that on the western side of the continent, from Cape Horn, to the northern Arctic Ocean, *one vast anticlinal axis exists*, along the crest of the Andes and the Rocky mountains. Subordinate and perhaps intersecting systems of strata will undoubtedly be found along the extended line, but this appears to be the grand controlling, and probably the most recent, uplift of the continent. . . . The Appalachian range of mountains forms *another anticlinal ridge*, extending northeasterly through New England, and not improbably to Labrador" (pp. 264-265).

In the Elementary Geology before quoted, Dr. Hitchcock amplifies his defense of the metamorphic theory then recently introduced into geology by Alexander Brongniart. The main points stated are briefly these: 1. It shows why, amid so much evidence of chemical agency in the formation of the primary rocks, there is still so much proof of the operation of mechanical agencies. 2. It shows why silicates predominated in the earlier periods of the globe, and why limestone and carbon were more abundant at the later periods. 3. It explains the absence of organic remains in the primary stratified rocks. 4. It explains, too, the reason why carbon is much less abundant in the older than in the newer rocks. 5. It explains the imperceptible graduation of gneiss into granite" (pp. 259-61).

Elementary Geology, pp. 36, 37. The subject is also taken up in his Anniversary Address (cited below,) p. 268.

†First Anniversary Address Before the Association of American Geologists at their Second Annual Meeting in Philadelphia, April 5, 1841. *Amer. Jour. Sci.*, vol. xli, pp. 232-275.

In the Anniversary Address from which I have quoted, Dr. Hitchcock considers briefly the origin of dolomytes :

"As to that portion of this field [of dolomite and dolomitic limestones] which has fallen under my observation, I find that with one or two unimportant exceptions, all the cases of dolomitized limestone occur either in the vicinity of a fault or of unstratified rocks, or of the oldest gneiss. The pure dolomite is usually found where there is reason to believe extensive dislocations of the strata occur; and the marks of stratification in the limestone disappear nearly in proportion to the amount of magnesia which it contains, so that the pure dolomite shows scarcely any traces of it. I doubt not that similar conclusions will follow an examination of other parts of this deposit, so remarkably uniform in the geology of this continent; — and moreover, these conclusions correspond to the history of dolomitization in Europe. They seem to render probable the theory of sublimation from the interior of the earth."*

1859. In the Final Report of the Geology of Vermont,† Dr. Hitchcock, who assumed the responsibility, as he tells us, though most of the field work was done by others, takes up early in the report, the subject of "The Metamorphism of Rocks" (p. 22). In the following language he sets forth his general conception of the *modus operandi* of hypogeal metamorphism.

"If the globe was once in a molten state, the crust which first formed over its surface must have been some kind of unstratified rock. When it became coal enough to allow water to condense on the surface and form oceans, the waves would wear away portions of the rock, and deposit the fragments in the form of gravel, sand and clays. These by the action of internal heat might be hardened, and become conglomerates, sandstones and shales. If new beds of materials should be thrown upon these strata it would cause the internal heat to penetrate further upward into the conglomerates, sandstones and shales, and, by the help of water, render the rocks plastic and convert them from mechanical into crystalline rocks, without destroying the planes of stratification, though generally obliterating all traces of organic structures which they might have contained, and changing the laminated structure into foliation and cleavage. After all this, water may have acted mechanically on these strata, wearing them away, and forming other deposits of puddingstones, sandstones and shales. Meanwhile also, the internal heat working farther upward, as it certainly would by the accumulation of new beds of detritus, might melt over the lower beds of the strata, converting them into unstratified rock. And thus might the same materials have been subject to repeated and most thorough metamorphosis" (p. 22).

---

*Amer. Jour. Sci., xli. 240.

†*Report on the Geology of Vermont, Descriptive, Theoretical, Economical and Scenographical.* By Edward Hitchcock, Edward Hitchcock, Jr., Albert D. Hager, Charles H. Hitchcock. 2 vols. 4to. Claremont, N. H., 1861. The preface is written by Dr. E. Hitchcock, and dated Oct. 1, 1859, and Oct. 2, 1860.

The writer then proceeds to an account of the "agents of metamorphism," heat and water, recalling the well known results of experiments and reasoning, and treats with considerable detail the evidences of "a former plastic condition of the rocks". He cites numerous observations, showing that rocks and rock-constituents must have been reduced to a plastic or semi-plastic condition, subsequent to their original consolidation, and so continued for a great length of time", In this connection he cites numerous instances of pebbles which have been elongated and flattened—some even at length being "converted into the silicious folia of schists, and the cement into mica, talc and feldspar". He refers to the pebbles near Newport, Rhode Island; others at intervals along the western side of the Green mountains, and especially a locality in Plymouth, Vermont, where pebbles occur under such forms as to indicate a state of plasticity. In Wallingford the beds of conglomerate thus altered alternate with beds of talcose and mica schist (pp. 28–38, 476). Some of the facts point toward the inference that schists and gneisses even may have originated from the extreme flattening and elongation of the pebbles of an original conglomerate, though as a fact, pebbles had not at that date been found actually occurring in gneiss. Dr. Hitchcock expects that such views would "be pronounced preposterous by able geologists*". In a syenitic rock, however, found in Vermont and Massachusetts, undoubted pebbles had been observed. Other facts have been noted by the writer: See, Conglomerates enclosed in Gneissic Terranes, *Amer. Geologist*, iii. 153-165; 256-261; *Sixteenth Ann. Rep.*, Minn. pp. 218-222, 334. He says:

"We define this rock as a conglomerate with a cement of syenite or granite, or as a syenite or granite with pebbles in it, sometimes thickly and sometimes sparsely disseminated". . . . "These facts certainly give great plausibility to the view which supposes granite and syenite to be often the result of the metamorphosis of stratified rocks" (pp. 40, 41; ii, 565, 566.*)

In connection with the discussion of metamorphism the writer

---

*Dr. Hitchcock's expectation has found fulfillment in the dissent recorded by Dr. M. E. Wadsworth *Bull. Mus. Comp. Zool.*, Geolog. Series, i; B. S. Lyman, *Proc. Amer. Assoc. Adv. Sci. 1866, p. 83.*

*See W. B. Rogers' views in opposition to those of Hitchcock stated in *Proc. Bos. Soc. Nat. Hist.* 1861 and *Amer. Jour. Sci.*, II, xxxi, 440-442, May, 1861.

reminds us of an inference which is too obvious to have fallen into such general forgetfulness. He says:

"Metamorphism shows us that the earliest formed rocks on the globe may have all disappeared. None of the first formed crust may remain. Or, if any of it is left, it would be impossible to distinguish it from subsequent formations. So that the idea of a primary granite or any other rock, in the strict sense of the term, has no foundation in nature" (p. 47.)

In close connection with this subject, we cite some passages from another chapter, touching the nature of foliation. Speaking of the gneissic rocks of Vermont, he says: "In certain districts the strata are exceedingly contorted, and the average dip and strike are the ones that we recorded. There is not a square mile of this rock in the State where there are not more or less of these irregularities. In a few instances, the difficulty of ascertaining the true position is so great that we have not attempted it."

After illustrating a striking particular instance of these contortions, he concludes:

"This state of things suggests two important topics: *First*, Do not these contortions prove that the layers that have suffered this twisting are the strata, and not the bedding of cleavage or foliation? For the beds between cleavage planes are rarely contorted. The strata may be contorted while the cleavage planes cross them with perfect regularity. In fact, the cleavage does not appear to have been produced until the strata had been quietly settled into their present positions, as a general thing." The *second* topic relates to the effect of contortion on calculation of thickness of terranes*.

Speaking of the position of the "red sandrock" of northern Vermont,". regarded by Emmons as belonging to the age of the Potsdam and Calciferous, Dr. Hitchcock says:

"Without an exception, it rests upon the Hudson River group. The stratigraphical evidence goes to show that the red sandrock is of the age of the Medina sandstone or Oneida conglomerate. This was the original view of Dr.Emmons, and has since been sustained by Professors C. B. Adams, W. B. Rogers† and W. E. Logan. It is certainly an objection to this view that the characteristic fucoid, *Arthrophycus Harlani*, of the Medina sandstone has never been found in it." (p. 340.) Compare A. D. Hager's description of "Red Sandrock mountains," (ii, 875.)

---

*Geology of Vermont, p. 518.

†A communication is cited from W. B. Rogers, which is said to have been prepared for the *Amer. Assoc.* at Albany in 1851, but not published, in which this view is argued (*Geol. Vt.*, p. 326.) This view of Dr. Hitchcock, he states later in his Report, (p. 435) "has now been changed."

In reference to the "Quartz rock" of the older geologists—the "Granular quartz," of Emmons, the "Potsdam sandstone" of the brothers Rogers, of Hall and later geologists, Dr. Hitchcock presents no facts decisive of the question of its position. As to the "Georgia slate"—the "Black slate" and "Taconic slate" of Emmons—the "Hudson River group" of Hall—the "upper part of the Hudson River group, or a distinct group above the Hudson River group" on the authority of Sir William Logan—a "primordial" terrane, as determined by Barrande—Dr. Hitchcock has no decisive facts to offer. He recites the principal data touching the lithological and stratigraphic characters of the group, and acquiesces in the verdict then recently rendered by Hall and Logan in reference to the geologic age, expressely disagreeing with Emmons in regard to any unconformity between the "Georgia slates" and the "red sandrock."

The "Stockbridge limestone" of Emmons, Adams and Thompson is christened "Eolian limestone" (from Mt. Eolus, or Dorset mountain). This is the "Granular limestone" of Dewey, and "metamorphic Trenton limestone" of Rogers, Logan and Hunt. The "Sparry limestone" of Emmons is included in it. As to their geological position, Dr. Hitchcock says: "We incline to the opinion that they must probably be placed as high as that [the Corniferous] formation, or as low as the Lower Silurian, to which last position Mr. T. S. Hunt assigns them. Either position abounds with difficulties, and we are hardly prepared to choose between them," (p. 421). He has changed his view in reference to dolomitization. He says:

"The old notions that it has been done by igneous fusion, or by the sublimation of carbonate of magnesia do not all satisfy the facts as we now understand them," (p. 424). He then quotes from Bischof to the effect that dolomytes can only be regarded as a product of the alteration of limestone in the wet way (p. 424).

The "Magnesian slate" of Dr. Emmons, and of Adams and Thompson, is described by Dr. Hitchcock under "Talcoid schists," because analysis shows that they are essentially aluminous (p. 425). He regards them as probably newer than the Eolian limestone (p. 433).

The theory of the metamorphic origin of granites gains strength in the mind of the author, and he returns to it with new thoughts and new supports. He points out the improbable assumptions of the theory of molten granitic protrusions, save in an exceptional way, (ii. pp. 572, 573), and enforces the arguments for aqueo-igneous fusion of pre-existing rocks as the most probable origin of granites (ii., 574–6). He maintains, 1. The accepted theory of igneo-aqueous softening for recognized schistose rocks needs only an extension in the same direction, to apply to granitic rocks. 2. The order of solidification of the constituents of granite has not been that which would have been followed in a case of cooling from a state of fusion. 3. The existence of hydrated simple minerals, or of such as must have been formed in the wet way, or of such as would undergo partial or entire decomposition, even at a red heat, is an evidence favoring the igneo-aqueous theory. 4. The character of thin tortuous granitic veins, instead of evincing molten fluidity, seems more probably to have resulted from a state of solution or softening in alkaline thermal waters.

Dr. Hitchcock never made an explicit record of his views in reference to the tenability of the Taconic system as a whole. He opposed the earlier views of Emmons in reference to a non-inversion of the strata in western Massachusetts—though at one time wavering on that subject—and is commonly ranked with the brothers Rogers as an opponent of Emmons' claims. But Hitchcock's conception of the assumed overturn was different from that of the brothers Rogers; and Emmons yielded at last, to the evidence of a *folded* overturn. In reference to the position of the "red sandrock" at Highgate and elsewhere, Hitchcock in the earlier portion of his Vermont report, deferred to the positive opinion of W. B. Rogers*, and in this respect was again at variance with Emmons, who held it to lie in the position of the Potsdam sandstone and the Calciferous sandrock†. As to the Georgia slates, which the majority of American geologists had pronounced equivalents of the Hudson River series, or newer, Dr. Hitchcock appears finally to waver. He quotes the changed opinions of Logan, and the positive assertions of Barrande, as well as Hall's explanations of his positions, and as to himself, confesses that he no longer takes sides—though apparently he admits, with Logan, that the Point Lévis rocks are subordinate to the Potsdam, instead of near the middle Silurian. But on still later pages‡, he compiles a resume of the Taconic system, saying, "We shall use the terms which are employed by Prof. Emmons, and shall endeavor to represent his ideas *as they are published*, as faithfully as though we were the amanuensis of an

---

**Proc. Amer. Assoc.*, Albany, 1851.

†*American Geology*, vol. 1, pt. ii., pp. 88, 128, 1855.

‡*Vermont Report*, pp. 434-447.

advocate of the Taconic system." This epitome, therefore, is not compiled in a controversial spirit. Moreover, it soon becomes manifest that some of the reasoning is Dr. Hitchcock's own; that is, he assumes the character of a friend and advocate. He concludes with a statement of "presumptions in favor of the Taconic system": "1. Its similarity to the Cambrian system in Europe." From this is deduced, "2. A presumption that the old doctrine of the Laurentian age of the New England azoic rocks is correct." "3. The Taconic rocks are physically unlike the Lower Silurian." "4, The Taconic system underlies the Lower Silurian." "5. The thicknesses of the Taconic and Lower Silurian rocks do not agree." "6. The organic remains of the Taconic and Lower Silurian rocks are entirely different from one another."

HENRY D. ROGERS.

1842. In their classic memoir "On the Physical Structure of the Appalachian Chain,"* the brothers Rogers say:

"At an early period in the geological surveys of New Jersey and Virginia, we were struck with the great prevalence of the southeasternly dip of the strata, throughout the portions of the Appalachian chain traversing those states, and recognized its dependence on the oblique or inverted folding of the strata. This will appear from the descriptions we have given in our Annual Reports for 1837 to 1839. The important general law of the greater steepness of the dip on the northwestern than on the southeastern sides of the anticlinal axes, became known to us at the same stage of our inquiries and was first announced in the Final Report on the geology of New Jersey, written in 1839, and published early in the spring of 1840" (p. 481).

Another anouncement of these views was made to the American Philosophical Society in January, 1841. †

After adverting to the statements of previous writers that all the strata between the Hoosac mountain [Massachusetts] and the Hudson river lie in an inverted order, drawings were exhibited, proving the existence of numerous closely folded anticlinal and synclinal axes; and the inference was drawn that the inverted dip of the rocks is a result of a folding of the beds at short intervals, and not of one general turning over of the whole series, as suggested by professor Hitchcock. Subterranean igneous action was referred to as having caused this compression and folding of the rocks, and its energy was shown to have been greatest along the

---

***Transactions of the Association of American Geologists and Naturalists*, 1840, 1841 and 1842 pp. 474-531.

†*Proc. Amer. Phil. Soc.*, Jan. 1, 1841.

Berkshire valley, and the ridges lying to the east. To the same agency was attributed the crystalline condition of the Berkshire marble and of the associated schists and semi-vitrified quartz rock— the first being regarded as merely the blue limestone of the Hudson valley, extensively altered, and the last, a highly altered form of the white sandstone at the base of the Appalachian formations (p. 482).

Speaking of the character of the flexures in the Hudson River division, they say:

"In this belt the flexures are, for the most part, of the closely folded type, and the dip is almost invariably toward the southeast, the compressed and oblique plication of the beds extending equally to the hypogene or primary rocks of the mountains bounding the valley in the east, and to the lower formations of the Appalachian system which occupy the valley itself" (p. 486).

"A feature of frequent occurrence in certain portions of the Appalachian bélt, is the passage of an inverted flexure into a fault" (p. 494). "It is an interesting general fact that the space between the axes, or, more properly, the amplitude of the undulations, increases as we cross the chain northwestward" (p. 507).

1844. These views have a bearing on the interpretation of the structure occurring on the east of the Hudson river, within the geographical limits of the Taconic system. In the light of them, professor H. D. Rogers used the following language in reference to the proposal of Emmons.*

"The fixing of a base for the Palæozoic rocks of the United States is a problem scarcely less difficult than that of determining the lower limit of the corresponding system of England, to which the admirable sagacity of Sedgwick has been so usefully directed. Do we possess, in the so-called Taconic system of rocks lying to the southeast of the unequivocally fossiliferous strata at the base of the New York or Appalachian system, an independent mass of formations of an unquestionably earlier date, or are these, on the other hand, but well known lower Appalachian strata disguised by some change of mineral type and by igneous metamorphosis? These Taconic rocks, under the form they assume along the eastern boundary of New York and the western side of Vermont and Massachusetts, have been carefully studied by Emmons, Hitchcock and Mather; all of whom appear to have arrived at different conclusions concerning them.† . . . Professor Emmons considers

---

**Amer. Jour. Sci.* xlvii. 150. Oct., 1844.

†Professor Mather's conclusions are embodied in the preface to the report on the *Geology of the First District of New York*, 1843, p. viii. Referring to the views of the pro-

the granular quartz, slate and limestone of the Taconic hills and the Stockbridge valley as constituting a distinct group of strata. . . . His principal argument in defense of this view is, that the order of succession of the component members of the group is essentially different from that witnessed in the sandstone, limestone and slate of the Champlain division, and he denies that the theory of plication of the beds, advanced originally by myself and my brother, and applied to this very region, can reconcile the seeming want of agreement. Now it is true that the apparent order of superposition in the Taconic belt is in discrepancy with the well known succession of the Champlain formations, but this is precisely what should arise from the introduction of those complete folds or doublings together of the strata which we have conceived to exist; and I would add that the sections furnished by professor Emmons and professor Mather in their reports, if resolved by the introduction of the flexures supposed by us, will all of them display, for their western portions at least, the normal order of superposition of the Champlain rocks. This identity of the so-named Taconic System with the formations of the Hudson and Champlain valley was announced by my brother and myself, in the beginning of 1841, to the American Philosophical Society. By the aid of a section from Stockbridge towards the Hudson river, we showed the existence of numerous close anticlinal folds, and thus explained the apparent inversion of the dip, which other geologists had ascribed to one general overturning of the whole series. The plication was shown to be greater along the Berkshire valley and the ridges west; the granular Berkshire marble was identified with the blue limestone of the Hudson valley, but metamorphosed by heat, and the associate micaceous, talcose and other schists were referred, in the language of the communication, to the slates of the formation of the Appalachian system; while the

---

fessors Rogers, he says: "I concur with them in this opinion. My own observations on these rocks (from the Hoosac mountain to the Hudson) and those of the Hudson valley, conducted with much care throughout their whole extent, in New York, and in Vermont and Massachusetts, through a series of years, have led me to the conclusion that they are metamorphic, and of the age of the Champlain division; that they are the altered limestones, slates and sandstones of that division . . . The white limestone containing plumbago and various crystallized minerals is another point on which there are various views. I have come to the conclusion that it is metamorphic, but in more highly metamorphic state than the dolomitic limestones of the Taconic rocks."

Chapter vii., however (pp. 422-438), is devoted to the "Taconic System". But, at the end, professor Mather remarks: "It will be observed by those who have read the preceding details in regard to the Champlain Division and the Taconic System, that they are considered to be the same rocks, the latter somewhat modified in character by metamorphic agency" (p. 438).

In the chapter on Metamorphic Rocks, he says: "In describing the Taconic rocks separately, I have yielded to the opinion of some of my colleagues who have considered them as interposed between the Champlain Division and the Primary. I can discover no evidence of any such interposition . . . " (p. 449).

semi-vitreous quartz rock of the western part of the Hoosac mountains was stated to be nothing else than the white sandstone (Potsdam sandstone) of the same series slightly altered. . . . It is true Professor Emmons has presented in his report, a series of sections of the strata exhibiting an unconformity at the passage of his Taconic into the rocks of the Champlain division, but I must take the liberty of expressing my disbelief of the existence of any such unconformity, and of observing that, in the prolongation southwestward of this altered and plicated belt, as far as the termination of the Blue Ridge in Georgia, a distance of one thousand miles, no interruption of the general conformity of the strata has ever met the observation of my brother or myself,"

"It would appear thus, that the Potsdam sandstone forms the base of the Palæozoic strata in the latitude of lake Champlain, or at least in the region of the lake and the Mohawk river" (pp. 151-152).

Professor Rogers adds some suggestions which in the light of later palæontological developments, must be regarded prophetic.

"Is this formation, then, the lowest limit of our Appalachian Palæozoic masses generally, or is the system expanded downwards in other districts by the introduction beneath, of other conformable sedimentary rocks? From the Susquehannah river southwestward, a much more complex series of strata comes in below the bottom of the lowest limestone, than is anywhere seen northeast of the Schuylkill. In some portions of the Blue Ridge belt there are at least four independent, and often very thick deposits constituting one general group, in which the Potsdam, a white sandstone, is the second in descending order. The uppermost of these is an arenaceous and ferriferous slate, many hundred feet thick, in which the only fossil is a peculiar fucoid. Beneath this lies the Potsdam sandstone, and under this again, a mass of coarse sandy slate and flaggy sandstone, amounting sometimes to six or seven hundred feet, below which occurs in Virginia and East Tennessee,* a series of heterogeneous conglomerates. Neither of the two lowest of these masses has yet rewarded research with a single fossil" (p. 152).

---

* Professor Safford in his admirable digest of the "*Geology of Tennessee*" (pp. 151, 158 182) described the Potsdam group as composed of: 2c. The Knox Group of Shales Dolomites and Limestones; 2b. The Chilhowee Sandstone (Potsdam proper;) 2a. The Ocoee Conglomerate and Slates (Eozoic). Below these are the metamorphic rocks, gneiss, mica slate, syenite and chloritic slates. Dr. Safford says; "The metamorphic beds together with those of other groups that are adjacent or neighboring, all appear to follow the same law of dip and strike. The dip is, in the main, at a high angle to the southeast. . . . They all apparently belong to the same system of upheavals. . . . With reference to age, I have no reason for believing that the group within Tennesee includes the metamorphosed beds of any formation of more recent date than the Ocoee conglomerate and shales" (p. 177).

"Adjoining this great mass of arenaceous strata toward the southeast we find throughout much of the broad belt of the Blue Ridge, especially in its prolongation southwestward from the Potomac, a wide expansion of metamorphic strata intersected by innumerable veins and dykes of greenstone and other igneous materials, and displaying almost every grade and variety of alternation in texture and mineral contents. These, after long and careful observation, we have been led to consider as a group of sedimentary beds, still older than the preceding, but forming a part of one and the same unbroken series. Thus, then, in the great group of strata at the base of our lowest fossiliferous series, we are presented with similar and perhaps more striking results of igneous modifying powers than even in that portion of the Champlain system whose metamorphosed rocks constitute the Taconic group. . . . Respecting the phenomena presented in the long belt of rocks here referred to, the question suggests itself whether the so-called Taconic system instead of belonging exclusively to the Champlain division, may not, along with the western border of Vermont and Massachusetts, include also, some of the sandy and slaty strata here spoken of as lying beneath the Potsdam sandstone" (p. 153).

In his final Report on the geology of Pennsylvania, published in 1868,[*] professor Rogers, in speaking of the Second or Middle Belt of Gneiss, in the southern gneissic district, says: "It would seem as if these minerals had crystallized or segregated from their parent sedimentary materials, under a conflict of forces, the newly awakened crystallizing energies being not always parallel to the original bedding of the deposit, but more frequently oblique to it" (p. 71). This remark is made in view of the "wavy or minutely undulated lamination, arising apparently, from a contorted or wavy structure in the coarsely crystallized mica, its predominant mineral, which he thought, seemed "to proceed from the interference of innumerable planes of cleavage—or what is the same thing—of crystalline lamination, with the original planes of deposition of the strata."

He remarks a character which possibly might be attributed to remoteness of the upper gneisses from the zone of intense crystalline action:

---

[*] *The Geology of Pennsylvania, Government Survey*. By Henry Darwin Rogers. In two vols. 4to, New York, 1868. The author informs us in the preface that the survey was commenced in 1836; interrupted from failure of appropriations in 1842; revived in 1851 (after sundry failures in attempts to accomplish publication); the field work was concluded in 1855, report rewritten and placed in way of publication under direction of the author. The preface is dated Philadelphia, April, 1858.

"A remarkable feature in the northern or uppermost band of gneiss on the Schuylkill, or those which next adjoin the base of the Primal series, is the possession of a less than usual completeness of crystallization in the constituent minerals, the feldspar more especially, appearing to be less perfectly developed than common, and more in the condition of roundish or lenticular, segregated lumps. In this circumstance, the gneiss here approximates somewhat to the structure of the lowest beds of the Primal series, which are also porphyroidal, but exhibit their metamorphism in a far lower degree" (p. 73).

The prevailing Appalachian dip is not remarked in the gneisses:

"A remarkable feature in the structure of the whole southern gneiss district is the prevalence of a northward dip in the strata. This inclination prevails along the Schuylkill, with very few local and trivial exceptions throughout all the three great subdivisions of the zone of gneiss" (p. 78).

I make one more quotation, setting forth a conception in reference to Appalachian structure, which demonstrates long and thoughtful observation:

"That the wide area of gneiss now under description is undulated in a succession of anticlinal and synclinal waves is obvious to any practiced geological observer who studies its structure with due care. . . The notion of an undulated or folded structure in the gneiss finds corroboration in the parallel arrangement of the hills and valleys; and in the sudden changes in the dip of the strata, wherever we make a transverse section through the region; but it receives its most positive demonstration, when we study the topography and distribution of the gneiss on the western side of the county. There as we have already seen, several long tapering tongues of the gneiss formation project forward towards the W, including between them actual troughs of the Palæozoic rocks, a feature not attributable to any other mode of elevation of the gneiss than that of an undulation of its general floor in the manner of long anticlinal waves" (p. 86). In reference to inverted flexures in the South mountains, see page 94.

JAMES HALL.

1843. In his Final Report on the geology of the Fourth District of New York,* Mr. Hall, like Mr. Mather and Mr. Vanuxem,**

**Geology of New York. Part IV, Comprising the Survey of the Fourth Geological District.* By James Hall. Albany, 1843.

**Vanuxem's chapter on the Taconic system occupies but about one page (pp. 22,23.) The rocks of the system barely entered his district. Unlike Mather, he agreed with Emmons as to the validity of its existence. The following, however, is a curious paragraph:

makes mention of the Taconic system, then recently proposed by Dr. Emmons. But, with Mr. Hall, a mere mention suffices. He says: "II. Taconic System. Represented by the Taconic range of mountains in the eastern part of New York." (p. 17.)

1847. Mr. Hall's attitude toward the Taconic was disclosed in the first volume of the Palæontology of New York[*] where the trilobites described by Dr. Emmons under the names *Atops trilineatus*, and *Elliptocephalus asaphoides*, as representatives of Taconic life, were described as *Calymene beckii*, an authentic species of the Hudson River group, and *Olenus asaphoides*, presumed also to be of similar age. He says:

"Supposing the existence of a system of strata below the Potsdam sandstone, of which we have no proof, we might fairly infer that the wide interval between the deposition of those strata and the Hudson River group, would give us forms of animal life more widely different than these examples offer" (p. 257, note.)

1859. So far as I have observed, professor Hall had no occasion to assume positions bearing on any questions concerning pre-Silurian rocks, until some [assumed] "Trilobites of the Shales of the Hudson River Group" from northern Vermont, were placed in his hands.[†] These were described as *Olenus thompsoni*, *Olenus vermontana and Peltura* (*Olenus*) *holopyga* (pp. 59-62). These fossils, as it appeared, were obtained from the district claimed by Emmons as representing the Taconic system. Though these were not generic types characteristic of the horizon of the Hudson River group, the controlling reason for placing them there, is expressed in the appended note as follows:

"NOTE. In addition to the evidence heretofore possessed regarding the position of the slates containing the trilobites, I have the testimony of Sir W. E. Logan, that the shales of this locality are in the upper part of the Hudson River group, or forming a part of a series of strata which he is inclined to rank as a distinct group, above the Hudson River proper. It would be quite superfluous for me to add one word in support of the opinion of the most able

---

"It is a convenient receptacle for deposits which belong neither to the Primary nor the New York System; and the mind in England is disposed to one of the kind. since the Cambrian System holds the same position. From [To] the necessity of a connecting link between the Primary and the Secondary classes, which alone existed when Werner rose as a geologist, we owe the Transition class, the fruits of which are the Cambrian System of Mr. Sedgwick. the Silurian of Mr. Murchison, and the Devonian of Mr. Phillips; now merged, with the exception, probably, of a portion of the Cambrian, in the New York System.'

[*] *Palæontology of New York*, Volume I. By James Hall, 1847.

[†] *Twelfth Annual Report of the N. Y. Regents. Contribution to the Palæontology of N. Y., 1855, '56, '57 and '58.* By James Hall. 1859. Professor Hall has informed us that this report was published previous to Sept. 20, 1859.

stratigraphical geologist of the American continent" (p. 62, note.)

1860. In the Thirteenth Report of the Regents[*], professor Hall changed the generic references of the three trilobites just mentioned, establishing for them, two new genera. They are here described (the first with a new figure) under the names *Barrandia thompsoni*, *Barrandia vermontana* and *Bathynotus holopyga*. The technical reasons for these changes are explained. In reference to geological position, he says, in a paragraph at the end:

"The geological horizon of the shales in which these trilobites occur, having been made a matter of discussion among geologists, I shall refer those interested in the subject to the forthcoming report upon the Geology of the State of Vermont, by Professor E. Hitchcock," (p. 119, see anté, p. 99).

1861. This reference of the Georgia trilobites a horizon as high as the Hudson River group, was questioned and somewhat sharply criticised by M. Barrande[†] in 1860. Professor Hall, accordingly, made a restatement of the reasons which induced him to refer the Georgia trilobites to the Hudson River horizon. The truth of history, not to say justice to professor Hall, demands the quotation of some passages.[‡] After stating that Sir William Logan had authorized in an explicit manner, the note appended to his paper in the *XIIth Regents' Report*, he proceeds:

"Later discoveries in the limestones associated with the shales at Quebec leave no longer a doubt, if any could have been entertained before, that the shales of Georgia, Vermont, are in the same relative position [i. e., of Quebec age, instead of Hudson River] and we must regard these three trilobites as belonging to the same fauna with the species enumerated by Sir William Logan as occurring in the Quebec group. Left to palæontological evidence alone, there never could have been a question of the relations of these trilobites, which would at once have been referred to the Primordial types of Barrande.

---

[*] *Appendix. Contributions to Palæontology, 1858 and 1859, with additions in 1860.* By James Hall. This report, according to a slip attached to *XIVth Report*, was published before Dec. 17, 1860.

[†] *Neues Jahrbuch für Geologie und Petrefaktenkunde.* A translation of the letter written under date of Paris, July, 16,1860 to Prof. Bronn is given by M. Marcou, in a memoir entitled "On the Primordial Fauna and the Taconic System, By Joachim Barrande. With additional notes." From the *Proceedings of the Boston Society of Natural History*, vol. vii., Dec., 1860, pp. 369-382. Republished in *Amer. Jour. Sci.*, II., xxxi, pp. 212-15, Mar., 1861. M. Barrande wrote of these fossils: "Their primordial nature cannot admit of the least doubt, when the descriptions are read, accompanied with wood engravings which the large dimensions of these three species render sufficiently exact......All the characters of these three trilobites, as they are recognized and described by J. Hall, are those of the trilobites of the Primordial fauna of Europe. . Such is my profound conviction, and I think any one who has made a serious study of the trilobitic forms, and of their vertical distribution in the oldest formations will be of the same opinion" (pp. 371-372.)

[‡] *Amer. Jour. Sci.*, II, xxxi, pp. 220-6, March, 1861; *Canad. Naturalist*, vi, 113-20, Apr. 15, 1861; Geol. Vermont, i, 382-6.

"Sir William Logan yields to the palæontological evidence, and says, 'there must be a break.' He gives up the evidence of structural sequence which he had before investigated, and considered conclusive; and having heretofore [myself], relied upon the opinion of the distinguished geologist of Canada, in regard to a region of country to which my own examinations had not extended, I have nothing left me but to go back to the position sustained by the palæontological evidence." *

He then examines the palæontological evidence, and from a tabular exhibit of Quebec fossils, concludes:

"In the table we find, of previously recognized tribolites of the primordial faunæ, four genera and eight species; two genera before known in the Potsdam sandstone, and seven species; and of *Agnostus*, which is of the first and second faunæ, two species; and one new genus, with nine species."

"These are certainly very curious results; and a modification of our views is still required, to allow four genera and eight species, or, leaving out *Amphion*, three genera and six species of tribolites of the second fauna, to be associated with two genera and five species of tribolites of the primordial fauna, and yet regard the rocks as of primordial origin" (pp. 224). . . .

"In the present discussion, it appears to me necessary to go further, and to inquire in what manner we have obtained our ideas of a primordial or of *any* successive faunæ. I hold that in the study of the fossils themselves, there were no means of such determination prior to the knowledge of the stratigraphical relations of the rocks in which the remains were enclosed. There can be no scientific or systematic palæontology without a stratigraphical basis. Wisely then, and independently of theories, or of observations and conclusions elsewhere, geologists in this country had gone on with their investigations of structural geology. The grand system of Professors W. B. and H. D. Rogers had been wrought out, not only for Pennsylvania and Virginia, but for the whole Appalachian chain, and the results were shown in numerous carefully worked sections. In 1843, '44 and '45, I had myself, several times crossed from the Hudson river to the Green mountains, and found little of importance to conflict with the views expressed by the Professors Rogers in regard to the chain farther south, except in reference to the sandstone of Burlington, and one or two other points, which I then regarded as of minor importance."

---

* *Amer. Jour. Sci.*, II, xxxi, 221.

"Sir William Logan had been working in the investigation of the geology of Canada; and better work in physical geology has never been done in any country."

"This, then, was the condition of American geology, and investigators concurred, with little exception, in the sequence based on physical investigations. As I have before said, our earliest determinations of the successive faunæ depend upon the previous stratigraphic determinations. This, I think, is acknowledged by Mr. Barrande himself, when he presents to us as a preliminary work, a section across the centre of Bohemia. With all willingness to accept Mr. Barrande's determination, fortified and sustained as it is, by the exhibition of his magnificent work upon the trilobites of these strata, we had not yet, the means of parallelizing our own formations with those of Bohemia by the fauna there shown. . . . It then became a question for palæontologists to decide whether determinations founded on a physical section, in a disturbed and difficult region of comparatively small extent [i. e. Sir W. E. Logan's on the borders of Canada and Vermont] were to be regarded as paramount to determinations founded on examinations, like those of the Professors Rogers, extending over a distance in the line of strike of five or six hundred miles; and those of Sir William Logan over nearly as great an extent, from Vermont to Gaspe." . . .

"It is evident that there is an important and perplexing question to be determined. . . For myself, I can say that no previously expressed opinion, nor any 'artificial combinations of stratigraphy previously adopted, by me, shall prevent me from meeting the question fairly and frankly" (pp. 224-5-6).

1862. The new evidences in reference to the age of many of the rocks in the valley of the Hudson, led professor Hall to an abandonment, at least for a time, of the use of the term Hudson River group, for the assemblage of strata next above the Trenton group. In a note at the end of his report on the geology of Wisconsin, he records this changed position.*

"At that time [when the final reports on the geology of New York were in preparation] and at a later period, Dr. Emmons proposed the name Taconic System for a series of rocks lying a considerable distance to the eastward of the Hudson River, and which were, according to the author of that System, below the Potsdam sandstone. An examination of the slaty rocks of the System in some of their typical localities, proved, in the opinion of the writer, that

---

**Report on the Geological Survey of the State of Wisconsin*, vol. I. Jan. 1862, pp. 47 and 443-5.

they rested upon the Potsdam sandstone; and in tracing the same beds toward the Hudson River, there could be discovered no break or interruption in the strata anywhere to the east of that river. . . At a subsequent period, Dr. Emmons extended the application of the term Taconic System to the rocks of the Hudson River valley, including the area originally regarded as the typical locality of the Hudson River Group. . . Within the last few years, the discussion of the subject has been revived, more particularly from discoveries of fossils in Vermont and Canada, which prove conclusively that these slates are to a great extent, of older date than the Trenton limestone."

"Looking critically at the localities in the Hudson valley which yield the fossils [belonging to the second fauna] we find them of limited, and almost insignificant extent. . . Besides the fossils just mentioned, we know of no others for nearly a hundred miles along the Hudson valley, with the exception of the Graptolites, which have heretofore been referred to the age of the other fossils found in the smaller outliers, or to the second fauna, but which in reality, hold a lower position, and belong to the great mass of the shales below."

"Until recently but one or two other species of known older types of fossils (those of the Primordial fauna) had been discovered in these slates. But within the past few years, the number discovered has been very great. . . We are therefore satisfied. . . that the term Hudson River group cannot properly be extended to . . . the Lorrain shales and the shales and sandstones of Pulaski, etc. . . I have therefore dropped the term Hudson River group in its application to the rocks of Wisconsin which are of the age of the Lorrain shales of New York, and the 'blue limestone' of Ohio." . .

1864. The field examination made in 1864 in company with Sir W. E. Logan, has already been mentioned. *Ante*, p. — This resulted in the recognition of a wide distribution southward, of rocks belonging to the Quebec and Sillery formations. These identifications were made in the midst of a region which had generally been regarded as underlaid originally by altered strata of Hudson River age.

1877. The conclusions reached in 1861 and 1862, in reference to the age of the mass of rocks along the east side of the Hudson river, were found to be only partially true.* Later investigation showed the existence along both sides of the river, of a body of

---

*"Note upon the History and Value of the term Hudson River group, in American Geological nomenclature." *Proc. Amer. Assoc.*, Nashville, 1877, pp. 258-65.

slates lying in unquestionable continuity with the Lorrain shales of the Mohawk valley and the northwestern part of the state, and professor Hall therefore reclaimed the term Hudson River group as appropriate. No particular citations of reasons assigned is needed here. Professor Hall however, still recognized the existence of a mass of slates farther east in New York, which contained fossils of the Primordial fauna. These, therefore, still remained, to validate, as far as they could, Dr. Emmons' contention for the existence of a pre-Silurian, fossiliferous system.

SIR WILLIAM LOGAN.

1845. The first record of observations made by Sir William Logan on the range of rocks here under consideration[*], speaks of them collectively, as the "Metamorphic Series." But he recognizes a lithological and chronological subdivision.

"To the south of the Mattawa and of the Ottawa in its continuation after the junction of the two streams, important beds of crystalline limestone become interstratified with the syenitic gneiss,and their presence constitutes so marked a character that it appears expedient to consider the mass to which they belong as a separate group of metamorphic strata, supposed, from their geographical position and general attitude, to overlie the previous rock conformably. The limestone beds appear to be fewer at the bottom than at the top of the group, but whether few or many, they are always separated by beds of gneiss which in no way differ in constituent quality or diversity of arrangement from the gneiss lower down, except in regard to the presence of accidental minerals, the most common of which are garnets," (pp. 41, 42).

The facts stated would seem to afford but slender ground for the recognition of two "groups."

But this grouping is traced over an extent of sixty-three miles, when the result of his observations is expressed in the following arrangement:

4. Fossiliferous limestone [with Niagara fossils.]
. Greenish sandstones [of undetermined relations.]
2. Chloritic slates and conglomerates [subsequently Huronian.]
1. Gneiss (p. 67.)

1846. The series on the north shore of lake Superior is further described in the report of the following year[†]. The order of succession determined is given below:

5. Sandstones, limestones, indurated marls and conglomerates, interstratified with trap.

---

[*] *Report of Progress of the Canada Geological Survey for 1845-6*, pp. 40-45.
[†] *Report of progress for 1846-7*, pp. 8-17.

4. Bluish slates or shales, interstratified with trap. [Huronian Animike.)
3. Chloritic and partially talcose and conglomerate slates.
2. Gneiss.
1. Granite and syenite.

On these Mr. Logan makes the following remarks:

"The rock at the base of the series is a granite, frequently passing into a syenite by the addition of hornblende; but the hornblende does not appear to be often present wholly without the mica. . . This granite appears to pass gradually into a gneiss, which seems to participate as often in a syenitic as a granitic quality. . . The gneiss is succeeded by [3] slates of a general exterior dark green color, often dark gray in fresh fractures, which at the base appear occasionally to be *interstratified* with beds of a feldspathic quality, of the reddish color belonging to the subjacent granite and gneiss. . . Some of the beds have the quality of a greenstone, others, that of a mica slate, and a few present the character of quartz rock. Rising in the series, these become [4] interstratified with beds of a slaty character, holding a sufficient number of pebbles of various kinds to constitute conglomerates. The pebbles seem to be of various qualities, but apparently all derived from hypogene rocks. . . [Ogishke conglomerate?] "The formations which succeed [5] rest *unconformably* upon those already mentioned. The base of the lower one where seen [in Thunder Bay] in contact with the subjacent green slates presents conglomerate beds, probably of no great thickness, composed of quartz pebbles chiefly, with a few of red jasper, and some of slate in a green arenaceous matrix, consisting of the same materials in a finer condition." [Afterward "slate conglomerate."]

The [5] sandstones, limestones, indurated marls and conglomerates, are said to be crowned by an enormous amount of volcanic overflow.

In the light of our own studies, it becomes easy to recognize in No 3 the rocks of the Keewatin iron-bearing series, represented on the south shore by the Marquette iron-bearing series; in No. 4, the chloritic diabase slates of the Thessalon valley, and in No. 5, the "slate conglomerate" and quartzites and Trap-rocks of the same regions, and the Animike slates of northeastern Minnesota,* while the crowning overflow is the great gabbro sheet so widely spread in northern Minnesota.

---

*Erroneously supposed by Whitney and Wadsworth to represent the Cupriferous formation of the south shore (*Azoic Rocks*, p. 334). As the Cupriferous is with them of Potsdam age, we should have an astonishing equivalency between the Potsdam sandstone and the Animike black slates.

It is important to keep in mind the early recognition of an unconformity between the two series of schists Nos. 3 and 4, and the existence of quartzose pebbles in the bluish slates,* as in the blackish slates of the Thessalon valley.

1847. In order to describe the grounds of director Logan's determinations respecting the geology of the region north of lake Huron it is necessary to make a quotation from Mr. Murray's report of a survey in 1847.†

"The older groups observed, consist firstly, of a metamorphic series composed of granitic and syenitic rocks in the forms of gneiss, mica slate and hornblende slate; and secondly, of a stratified series, composed of quartz rock or sandstones, conglomerates, shales and limestones. . . . On a cluster of small islands, . . . granite was found breaking through the quartz rock. The color of the rock [which rock ?] was red. On one of the islands, quartz rock beds on opposite sides of the granite, were observed to dip in opposite directions, north on the north side, and south on the south side, at an angle of 78° or 80°; and in another of the islands, the quartz rock and granite were seen in juxtaposition, the former reclining on the latter. In this case the quartz was traversed by several trap dikes running slightly oblique to the strike, while granitic veins ran transversely through the whole, and were continued through the main body or nucleus of the granite, the one granite being distinguishable from the other notwithstanding the red color of both, by the finer texture of the veins" (pp. 112, 113).

This is the earliest description of a portion of the rocks in what was to become "the original Huronian region." An examination of the statements made by Mr. Murray justifies the conclusion that the rocks described correspond to the 'upper group' found by Logan on the north shore of lake Superior. But it will be seen that Logan parallelizes them with the *metamorphic* series of the north shore, without paying due regard to the unconformity which he has described running between the upper and lower groups. Thus, in reference to the second series of Mr. Murray, he writes in 1848 : *

---

* These are described as *black* argillaceous slates by Mr. Alexander Murray (same report, pp. 51-3) After noticing the two groups and the structurally *conformable* passage of the lower into the bottom gneisses, he says of the upper (black argillaceous slates) "The base of this formation . . . was observed on the Kaministiquia, near the Grand Falls. Its immediate junction with the rock on which it reposes was concealed from view, but appears to be indicated by the position of a small lake or pond occurring just below the second portage, and the marshy ravines which run from it in the direction of the strike on each side. The slates visibly reach to within a short distance of the pond, probably brought into place against the syenite by a dislocation.

† Murray, *Report of Progress for 1847-8.*

"The series of rocks occupying this country form the connecting link between lakes Huron and Superior to the vicinity of Shebawenahning, a distance of 120 miles, with a breadth in some places of ten, and in others exceeding twenty miles, and it appears to me, must be taken as belonging to one formation; on the west it seems to repose on the granite which was represented in my report on lake Superior as running to east of Gros Cap, north of Sault Ste. Marie ; on the east, the same supporting granite was observed by Mr. Murray, north of La Cloche, between three and four miles in a straight line up the Rivière au Sable, . . . and again about an equal distance up another and parallel tributary, . . . in both cases, about ten miles from the coast. . . . In respect to the geological age of the formation, the evidence afforded by the facts collected last year by Mr. Murray, . . . is clear, satisfactory, and indisputably conclusive. . . . The chief difference in the copper-bearing rocks of lakes Huron and Superior seems to lie in the great amount of amygdaloidal trap present among the latter, and of white quartz rock or sandstone among the former. But on the Canadian side of lake Superior, there are some considerable areas, in which important masses of interstratified greenstone exist without amygdaloid, [this is the 'upper group'] while white sandstones are present in others, as on the south side of Thunder Bay, though not in the same state of vitrification as those of Huron. But notwithstanding these differences, there are such strong points of resemblance in the interstratification of igneous rocks, and the general mineralized condition of the whole, as to render their positive approximate equivalence highly probable, if not absolutely certain; and the conclusive evidence given of the age of the Huron, would thus appear to settle that of the lake Superior rocks, in the position given to them by Dr. Houghton, the late state geologist of Michigan, as beneath the lowest known fossiliferous deposits, a position which, as will be seen by a reference to the Report of Progress I had the honor to submit to your Excellency, in 1846, appeared to me to derive some support from evidences on the Canadian side of lake Superior itself."

The positive error embodied in the foregoing paragraph is the attempt to parallelize the Huron rocks with a series of Superior rocks which consists of two groups, and then having shown the parellelism with the higher group, the drawing of inferences touching a

---

* *Report on the north shore of Lake Huron*, Dec. 29, 1848, pp. 8, 9, 19, 20.

third geological region which are valid only in reference to the lower Superior group.

The foregoing citation from the report of 1848, was embodied in a communication made by director Logan to the British Association in 1851.* But in place of the last part of the last sentence, we find the following: "and in this sequence, those [rocks] of Lake Huron, if not those of Superior, would appear to be contemporaneous with the Cambrian series of the British Isles." In the next paragraph, he says the Lower Silurian, on the lower St. Lawrence, "appears to rest upon gneissoid rocks, without the intervention of the Cambrian" (*Amer. Jour. Sci.*, l. c., p. 226;) and in the next, he uses the phrase, "Cambrian formation of Lakes Huron and Superior" (p. 227), and the same again on the next page. It is clear then, that in 1851, Sir William Logan considered the rocks on the north shore of lake Huron as equivalent to the Cambrian of Sedgwick.

1848. We must again cite from Murray, as it appears that director Logan's judgments were largely based on assistant Murray's facts. In the report for 1848–9, after describing the country along the Spanish river, he says:

"The geological formations met with in the region thus described, may be arranged in two groups, one of which appears to be nearly allied to, and the other identical with, the older rocks of which mention was made in my report of 1847–8. They are

2. Quartz rock group.
1. Granitic or Metamorphic group.

Mr. Murray, in describing the lower group, mentions only granitoid rocks. He says: "The constituent minerals were usually those of granite or syenite, or a mixture of both. . . A gneissoid structure was observed on one or two occasions, . . but obscure and ill defined." Speaking of the "Quartz rock group," he says:

"The rocks of this group, where they came under our observation, like those examined the previous season, were found to be partly of aqueous and partly of igneous origin." After describing the quartzose members, he speaks of the slate. "The slates were gray, green or blackish in color, and were usually more or less silicious, and frequently very micaceous. . . The more purely argillaceous portions of the slate were generally *black* or of a *very dark brownish* tinge, and in these a very symmetrical jointed structure, dividing the rock into rhombohedral forms of considerable regularity, was frequently recognized. The slates were very

---

**Rep. Brit. Assoc. Adv. Sci.* 1851. Trans. Secs. 59–62 *Amer. Jour. Sci.* II, xiv, 224–229. See also *Bull. Soc. géol. de France*, 1849–50, (2), vii, 207-209.

often observed to pass into a conglomerate, holding pebbles of granite and syenite chiefly, varying in diameter from an eighth of an inch to a foot, and imbedded in a *black argillaceous matrix*" (p. 37.)

No one who has seen Logan's slate conglomerates in the valley of the Thessalon, can fail to recognize the identity of the argillaceous slates described by Mr. Murray.

1849. In the report for 1849–50, director Logan describes the geology about Bay St. Paul and Murray bay. He classifies the rocks as follows:

4. Bituminous limestone (Trenton.)
3. Calciferous sandrock.
2. White quartz rock (Potsdam sandstone.)
1. Metamorphic group (p. 8.)

Referring to the "Metamorphic group," he states that the prevailing rock of the country is gneiss, sometimes of a granitic and sometimes of a syenitic character. After careful local details, he says:

"The gneiss of this district belongs to that metamorphic group of rocks, which in previous reports has been described as existing on the Ottawa, and as traceable thence . . to Cape Tourmente below Quebec. . . None of the highly crystalline limestones which on the Ottawa are so marked a feature of the group, were observed in the region under attention."

This fact gives support to the suggestion of Whitney and Wadsworth that the Laurentian limestones may be mere segregations, instead of extensive strata.

A white, translucent, slaty quartz rock, rendered cleavable by the presence of silvery mica, but seen only at three points, directly overlies the gneiss. "There appears to be little doubt that this rock is equivalent to the Potsdam sandstone of New York" (p. 10.)

1851. This year director Logan and assistant Murray examined different portions of the district between the Ottawa and the St. Lawrence. Mr. Logan describes the Potsdam sandstone as reposing unconformably on the "Metamorphic or gneissoid group" (p. 6.) The character of this "group" may be learned from Mr. Murray's description of the geology of Rigaud mountain (*Report of Progress*, p. 63.) After speaking of the occurrence of gneisses, he says:

"These beds are *interstratified* with others of a different character; one set is composed of small cleavable forms of black hornblende and grains of translucent, yellowish-white feldspar, weathering opaque-white, and crystals of brown mica. Another consists of grayish-green cleavable pyroxene, with individuals of greenish feldspar weathering white, and largely disseminated grains of magnetic iron; and a third consists of translucent albite, with black hornblende and magnetic iron ore disseminated, alternating with micaceous layers. All these beds are intersected by transverse dykes, some of which are fine-grained, grayish-black trap, probably a greenstone with disseminated grains of calc-spar, while others are porphyritic, having a fine grained blackish-green base, with individuals of greenish white feldspar" (pp. 63-64.)

This passage sounds very unlike the descriptions of the rocks about Spanish and Thessalon rivers. But these are the rocks which in the Seigniory of Rigaud, rest directly upon the gneisses. It is further stated (pp. 60, 65,) that at the base of 71 feet of sandstone, on Bluff island in Charleston lake, is a "red talco-quartzose rock of the Metamorphic series." No such rock is described in the region north of lake Huron. There is reason to suppose another group of rocks rests in this region in a position between the gneiss and the "Huron rocks."

Of the deeper gneisses Mr. Murray supplies some interesting information:

"Near Furnace Falls, on the second lot of the eighth concession of Landsdowne, there is a considerable display of crystalline limestone, holding as usual, spangles of graphite and mica, with grains of quartz. . . Crystalline limestones are also, extensively exhibited in the neighborhood of Beverly, township of Bastard, and Newboro' in south Crosby. Their color is usually white, but sometimes grayish-white, or white with gray bars or stripes. Small scales of graphite are invariably disseminated through the rock, with serpentine, mica and iron pyrites. . . The texture of the limestones is usually coarse. . . Nodular masses of vitreous white quartz, surrounded with thin layers of brown mica, and both enclosed in foliated green pyroxene, are met with in some of the beds. . . On the twenty-fourth lot of the tenth concession of Bastard, there is an unmistakable bed of *conglomerate*, interstratified between two beds of highly crystalline limestone, showing the sedimentary origin of the Metamorphic series. The following is a condensed statement of the section given (p. 62.)

7. Crystalline limestone, white, coarse-grained, 6 ft.
6. Crystalline limestone, fine, very hard, bluish-gray, 4in.
5. Calcareous sandstone, fine-grained, 2 in.
4. Coarse conglomerate. The pebbles are flat and lie on their sides, etc., 1ft. 6in.
3. A calcareous aggregate of quartz, with feldspar, calc spar and scales of graphite, 2in.

2. An aggregate of colorless, translucent quartz, with feldspar and patches of greenish, chloritic limestone, with brown mica, 4in.

1. Pure white, highly crystalline, coarse limestone, 5ft.

1852. Director Logan returns to an exposition of the rocks north of lake Huron,[*] and states:

"On Lake Huron, the Lower Silurian group rests unconformably upon a silicious series, with only one known band of limestone, about 150 feet thick, with leaves of chert in abundance, but as yet, without discovered fossils. This series is supposed to be of the Cambrian epoch. It comprehends the Copper-bearing rocks of that district, and with its igneous, interstratified masses, has a thickness of at least 10,000 feet. The gneissoid group, of which mention is made, is probably still older than this. Its conditions appear to me to make it reasonable to suppose that it consists of aqueous deposits in an altered state."

1854. The first announcement of the term Laurentian, as the designation of a series of rocks, was made in 1854.[†]

"The name which has been given in previous reports to the rocks underlying the fossiliferous limestones in this part of Canada, is the "Metamorphic series;" but inasmuch as this is applicable to any series of rocks in an altered condition, and might occasion confusion, it has been considered expedient to apply to them for the future, the more distinctive appellation of the *Laurentian series*,[‡] a name founded on that given by Mr Garneau, to the chain of hills which they compose."

In the same report, Mr. Murray, writing of the region between lake Ontario and lake Simcoe, supplies a general description of the Laurentian series, in these words:

"They consist of masses of micaceous and hornblendic gneiss, and masses of crystalline limestone interstratified by gneiss. In the great masses of gneiss, the prevailing color appears to be reddish, but they are frequently striped with interstratified bands of gray, the reddish part taking its general aspect from the reddish feldspar which is the principal constituent, while the gray is chiefly made up of small grains of white quartz and feldspar, with small scales of black mica, and occasionally grains of black hornblende. . . Beds also occur of which almost the only constituent is white quartz, and these often alternate with thin layers of yellowish white feldspar," (pp. 81, 82).

---

[*] *Quar. Jour. Geol. Soc.*, viii, 210, 1852.

[†] *Report of Progress, Geolog. Surv. Canada, for the year 1852-3*, Quebec, 1854, p. 8.

[‡] The term "Laurentian" had already been applied, in 1851, by Edward Desor, to the fossiliferous marine Drift of the valley of the St. Lawrence river (*Proc. Boston Soc. Nat. Hist.*, Feb. 19 and March 5, 1851, vol. IV, pp. 29, 33.) It was also published in the *Bulletin of the Geological Society of France* in the same year and in 1852; in the Neues Jahrbuch for 1853; and in Thompson's *Natural History of Vermont*, in 1853.

The term "Algonquin terrane" was also preoccupied by Desor, in 1851, as the designation of the fresh-water deposits about the Great Lakes, to which C. H. Hitchcock and J. D. Dana have since applied the term Champlain. The name "Algonkian" has been (in 1889) proposed by C. D. Walcott, for all the sub-Cambrian deposits down to the top of the crystalline schists. Thus a notable parallelism exists in the fortunes of the two terms proposed by Desor, for two distinct members of the Quaternary.

For a history of the use of the term "Laurentian as applied to a Quaternary terrane," see Joseph F. James in *American Geologist*, Jan. 1890. pp. 29-35; also C. H. Hitchcock, in *American Geologist*, April 1890, and Jules Marcou, in *American Geologist*, vol. VI, p. 64.

Various beds of crystalline magnesian limestone are described: —One on Eel lake 30 feet thick, and several other exposures on the same lake (pp. 83, 84); another on Long lake, seventh lot of ninth concession (with little magnesia), with apatite, silvery mica and graphite, and a few grains of rose-colored quartz, and some green serpentine; another below this, on Gold lake, with abundant grains and nodules of greenish serpentine; another, still lower, of white dolomite, with pinkish streaks and spots, with grains of quartz and serpentine (p. 84). Many other exposures are described, of similar general character. "Southwest from the Gold Lake limestone, in the continuation of the general strike, an exposure was met with on the fourth lot of the eighth concession. . . From the vicinity of this exposure, crystalline limestone is traceable, emerging from beneath the fossiliferous formations for a mile and a half" (p. 85).

If then these limestones are "low" in the gneissic series, an occurrence so near the fossiliferous limestones would imply the absence of a large part of the gneissic and the whole of the schistic rocks.

At an exposure on Birch lake, Mr. Murray measured a section, of which the following is a synopsis: (p. 89.)

11.	Mica slate, fine, with bands of coarse, disintegrating limestome	86ft.
10.	Limestone, coarse, disintegrating	40
9.	Feldspathic quartz rock and coarse disintegrating limestone	50
8.	Red, ferruginous mass, of brecciated appearance [See also p. 94]	10
7	Crystalline limestone, coarse, disintegrating	30
6.	Crystalline limestone, coarse, with graphite nodules and angular fragments of quartz	100
5.	Concealed from view	231
4.	Gneiss, mostly quartz, some black and brown mica and abundant garnets [Not very good gneiss]	260

3.	White quartz and fine-grained feldspar alternating	130
2.	Supposed to be chiefly mica schist	300
1.	Gneiss, red and gray, thin bedded, with layers of mica schist	132
		1369

1857. The reports of the Canadian survey for 1853, '54, '55, '56 were not printed until 1857.* In Murray's reports for 1853 and 1854, he describes the country between Georgian bay and the Ottawa river. "The Laurentian series" occupies most of the country. He speaks of *gneiss in alternation with mica slate.* Some highly garnetiferous portions are mostly an aggregation of granular quartz. He speaks also, of a black rock composed chiefly of hornblende, with some black mica (pp. 89, 90.) A fine grained red rock, supposed to be intrusive (p. 90) is spoken of, and beds of limestone are particularly located (pp. 91, 92, 93.) Bands of limestone are found about lake Nipissing (pp. 121, 122, 123.) The "Laurentian series" of lake Nipissing is further described in Murray's reports for 1855 and 1856 (Rep. 1857, pp. 140-3.)

"Among the boulders on lake Nipissing" says Mr. Murray, at the end of the report for 1855—printed in 1857, "many were observed to be of a slate conglomerate, and they were frequently of very great size; in their aspect and general character, these have a very strong resemblance to the slate conglomerate of the *Huronian series,*† from which, in all probability, they are derived" (p. 125.) In the report for 1856, he speaks of the bowlders of metamorphic rocks as derived from the Laurentian and Huronian formations on the north shore of lake Huron (p. 134.)

In reference to the red rock first mentioned in the report for 1853, (p. 90,) he says:

"At Grand Recollet Fall, in the north channel of the French River, and in the south channel about two miles southeast from them, the rock is of a brick red color, without any distinguishable lines or layers of stratification. It was supposed to be an intrusive syenite, and with a general breadth of from one to two miles, its course appeared to be N. N. W. and S. S. E., (141, 142.)

---

*The volume printed in 1857, of 404 pages, contains reports of Murray and Hunt for 1853, 1854, 1855, and 1856, and reports of Mr. Billings and Mr. Richardson for 1856.

†The term "Huronian" is evidently employed in this place, as a geographical designation, rather than the name of a well-considered historical assemblage of rocks occurring in the Huronian area and elsewhere. Systemically, these rocks were understood by Sir William Logan, as he tells us, to belong to the Cambrian (See *ante*, p. 116, 1852, in *Rep.* for 1851.) It will be remembered also, that Emmons had declared that they fall within the limits of the Taconic (See *ante*, p. 82, 1860, p. 18;) and it does not appear that the insistance upon the use of term Huronian has been formally defended—a lack of any attempt at justification which is explained only by the apparent assumption that the claims of Taconic were too preposterous to merit consideration.

Director Logan, in a note, suggests the resemblance of this red rock to some of the harder kinds of the *laterite* rock of the East Indies. He cites Dr. Clarke, as concluding, in 1838, that it results from decomposed syenite or hornblendic gneiss. "The Canadian rock," Mr. Logan adds, "seems to be a syenite in an incipient state of decomposition."

In his report for 1856, dated 1st March, 1857, Mr. Murray, speaking of the "distribution of the rock formations" between lake Nipissing and lake Huron, says:

"The rocks of the region explored during the season, embrace two of the oldest recognized geological formations, the Laurentian and Huronian; the rocks of the latter and more recent of which, have been observed to pass unconformably below the lowest of the fossiliferous strata of the Silurian system. The contorted gneiss of the Laurentian series, with its associated micaceous and hornblendic schists, spreads over the country to the south and east, while the slates, conglomerates, limestone, quartzyte and greenstone of the Huronian, occupy the north and western part" (p. 168). The boundary between the two coincides approximately with the White Fish river. The *immediate contact was nowhere distinctly seen* (168, 171). In passing "from the lower to the higher formation, a mass of rather coarse grained greenstone was generally met with." Mr. Murray gives, with many doubts, an approximate section of the Huronian series (p. 172), from which the following statement (omitting interpolated trap beds) is condensed:

6. Quartzyte, white and very pale sea-green, with beds of quartz conglomerate, the pebbles generally white opaque quartz, but sometimes red and green jasper.
5. Green, silicious, chloritic slates, and bands of quartzyte.
4. Slate conglomerate.
3. A band of limestone, much disturbed, often brecciated, pale whitish gray to dark blue.
2. Slate conglomerate, matrix always greenish, sometimes slaty, sometimes resembling a massive, fine grained greenstone; with many pebbles of white and red syenite, and occasional rounded masses of green, brown and red jasper.
1. Slate, fine grained, green, silicious with thin bands of green quartzyte; also, fine grained slates, sometimes greenish, often bluish or black, weathering very black; occasionally some layers of a reddish color.

The total thickness is supposed to be about 10,000 feet (p. 186). The dips of the rocks of this series are generally under 45°, but they locally vary from horizontal to 90°. The strikes vary from east northeast to west northwest. It appears to be a region of general disturbance. "An immense mass of magnetic trap" was found on White Fish lake. This is about midway between lake Wahnapitæ and island La Cloche in lake Huron, this, according to Hunt's analysis, contains "magnetic iron ore," magnetic iron pyrites" and "titaniferous iron." These facts remind one of the titaniferous and magnetic gabbro of northeastern Minnesota· Limestones are seen on the shore of lake Panache (p. 183). The eastern extremity of the La Cloche mountains is in a white or greenish quartzyte (p. 185).

Director Logan's report dated 3d March, 1857, after summarizing the work of Mr. Murray for the last five years, proceeds to trace the limestone beds of the "Laurentian Formation" in the neighborhood of Grenville and the Calumet river.

In a paper read before the American Association, in August, 1857,* by Sir William E. Logan "On the Division of the Azoic Rocks of Canada, into Huronian and Laurentian," he speaks of them confidently as "a series of very ancient sedimentary deposits in an altered condition." He refers to his suggestion of 1845, to separate the purely gneissoid portion from the portion consisting of interstratified gneisses and limestones, but says the evidence does not permit him to decide certainly which division is most ancient.

He next refers to what was published in the report of 1845, relative to the rocks on lake Temiscaming, consisting of silicious slates and slate conglomerates, overlaid by pale sea-green or slightly greenish-white sandstone, with quartzose conglomerates. The slate conglomerates are described as holding pebbles and bowlders (sometimes a foot in diameter) derived from the subjacent gneiss, the bowlders displaying red feldspar, translucent quartz, green hornblende and black mica, arranged in parallel layers which present directions according with the attitude in which the bowlders were accidentally inclosed. From this it is evident that the slate conglomerate was not deposited until the subjacent formation had been converted into gneiss, and very probably greatly disturbed; for while the dip of the gneiss, up to the immediate vicinity of the slate conglomerate, was usually at high angles, that of the latter did not exceed nine degrees, and the sandstone above it was nearly horizontal."

"In the Report transmitted to the Canadian Government in 1848, on the north shore of Lake Huron, similar rocks are described as constituting the group which is rendered of such economic importance from its association with copper lodes. This group consists of the same silicious slate and slate conglomerates, holding pebbles of syenite instead of gneiss; similar sandstones [quartzites?] sometimes showing ripple marks, some of the sandstones [quartzites?] pale-red green, and similar quartzose conglomerates, in which blood-red jasper pebbles become largely mingled with those of white quartz, and in great mountain masses predominate over them. But the series is here much intersected and interstratified with greenstone trap, which was not observed on Lake Temiscaming. These rocks are traced along the north shore of Lake Huron from the vicinity of the Sault Ste Marie, for 120 miles east." Sir William Logan continues, and indicates the existence of the same formation northeastward 130 miles farther, and as far as the Sturgeon river. The general bearing is northeast, and the dip appears to be almost northwest.

---

* *Proc. Amer. Assoc. Adv. Sci.*, 1857, II, pp. 44-47.

It would be erroneous to suppose that director Logan intended, in the foregoing citation, to say that the gneiss is *immediately* "subjacent" to the slate conglomerate containing gneissic pebbles. No contact between the slate conglomerate and the subjacent gneiss had been reported and it was impossible to affirm that the formation here described was chronologically successive to the gneiss.

"The group on Lake Huron," he continues, "we have computed to be about ten thousand feet thick, and from its volume, its distinct lithological character, its clearly marked date posterior to the gneiss, and its economic importance as a copper-bearing formation, it appears to me to require a distinct appellation, and a separate color on the map. Indeed, the investigation of Canadian geology could not be conveniently carried on without it. We have, in consequence, given to the series, the title of *Huronian*."

"A distinctive name being given to this portion of the Azoic rock, renders it necessary to apply one to the remaining portion. The only local one that would be appropriate in Canada is that derived from the Laurentide range of Mountains, which are composed of it from Lake Huron to Labrador. We have therefore designated it as the *Laurentian* series.*

Thus a new meaning was given to the term "Laurentian series," which, since 1854, had included all the Azoic rocks.

At the same meeting of the American Association, Sir William Logan read a paper, "On the probable subdivision of the Lauren-

---

*See also, *Canadian Journal*, 1857, ii, 439-442; *Canadian Naturalist and Geologist*, 1857, ii, 255-258.

tian series of rocks in Canada."[*] He described two beds of limestone which he had traced in the township of Grenville, on the Ottawa, running N. N. E., with indications that they belong to opposite sides of an overturned synclinal, with anticlinals of gneiss and quartz running parallel on the north and the south. A feature of these and other outcrops of limestone "is the occurrence immediately near the limestones, of immense masses of lime-feldspar. North of the Argenteuil band, eight miles examined across the stratification, consist almost entirely of it, in the form of Labradorite. . . Lime-feldspar is abundant at St. Jerome, and its stratified character is conspicuously displayed—the beds running parallel with the limestone. Mr. Hunt has traced a band of crystalline limestone for eleven miles, running diagonally across the township of Rawdon, in a north bearing. On the west side of this, lime-feldspar forms the great bulk of the rock exposures for twelve miles across the measures, and shows a well marked stratification."

"In Chateau Richer, below Quebec, a band of limestone occurs about a mile from the fossiliferous deposits, and to the northwest of it, lime feldspars present a breadth of eight miles. On an island near Parry's Sound, on Lake Huron, Dr. Bigsby observed the occurrence, *in situ*, of the opalescent variety of Labradorite, and the name of the mineral reminds us of the existence of the rock beyond the eastern end of the Province. It thus appears probable that a range of the rock will be found winding irregularly from one end of the Province to the other, of sufficient importance to authorize its representation by a distinct color on the map, and a distinct designation in geological nomenclature." [†]

1860. In a letter to M. Barrande, under date of December 31, 1860,[‡] Sir William Logan gives an exposition of the fauna of the Quebec group. Toward the end, he notes some recent observations which led him to qualify previous opinions in reference to the age of the Lake Superior sandstone:

"Mr. Murray has this season ascertained that the lowest rock that is well characterized by its fossils, in the neighborhood of Sault Ste Marie, near Lake Superior, really belongs to the Birdseye and Black River group, and that it rests on the sandstone of Ste Marie and Lacloche, the fossiliferous beds at the latter place being tinged with the red color of the sandstone immediately below them. These underlying Lake Superior rocks may thus be Calciferous and Potsdam, and may be equivalent to the Quebec group and the black colored shales beneath. The Lake Superior group is the upper Copper-bearing series of that region [consisting of 3. Potsdam; 2. Cupriferous; 1. "Slate conglomerates" etc., of lake Huron], and rests unconformably upon the lower Copper-bearing series, which is the Huronian system [as identified about Lake Superior] . . . Professor Emmons has long maintained, on evidence that has been much disputed, that rocks in Vermont, which in June, 1859, I for the first time saw and recognized as equivalent to the magnesian part of the Quebec group, are older than the Birdseye formation; the fossils which have this year been obtained at Quebec, pretty clearly demonstrate that in this he is right."*

---

[*] *Proc. Amer. Assoc.*, 1857, Pt. II, 47-51; *Canadian Journal* 1858, II, iii, 1-5; *Canad. Natur.* 1857, ii, 270-274.

[†] Dr. J. J. Bigsby, nevertheless, has recorded the opinion that the Huronian and Laurentian systems are intimately related in lithological character and conformable position. The reference being especially to the north shore of lake Superior (*Quar. Jour. Geol. Soc.*. 1863, xix, 36-52).

[‡] *Canadian Naturalist and Geologist*, v. 472-7.

1863. No other record on the subject of pre-Silurian rocks appears to have been made by Sir William Logan until the publication of the Geology of Canada, in 1863. This convenient and copious synopsis of Canadian geology, has subsequently been cited for authority, instead of the original reports, and in consequence, geologists have fallen into some misunderstandings."†

"The rocks which compose the Laurentian mountains" writes Sir William Logan, "were shown by the Geological Survey, in 1846, to consist of a series of metamorphic, sedimentary strata underlying the fossiliferous rocks of the province. . . . They are altered to a highly crystalline condition, and are composed of highly feldspathic rocks, interstratified with important masses of limestone and quartzite. Great vertical thicknesses of the series are composed of gneiss containing chiefly orthoclase or potash feldspar, while other great portions are destitute of quartz, and composed chiefly of a lime-soda feldspar, varying in composition from andesine to anorthite, and associated with pyroxene or hypersthene. This rock we shall designate by the name of *anorthosite*."

It can hardly be said that the survey established the conclusion that these rocks were sedimentary in origin; but it pointed out frequently, the evidences of such an origin, and certainly caused it to appear probable. The anorthosite rock referred to above includes the belt of Labradorite described in 1857, which was made the ground of an "Upper Laurentian" or "Labradorian" division. Of this division nothing is said in the general report of 1863. Speaking of the orthoclase gneiss, the writer says:

---

* This remarkable admission is alluded to by M. Barrande in these words "Terms so clear and possitive need no commentary. It is a formal recognition by Sir W. Logan of the Taconic system at the base of the lower Silurian. Professor Emmons could not wish the assent of a more respectable authority, which cannot fail to secure the adhesion of all American geologists ("Documens anciens et nouveaux sur la faune primordiale et le système Taconique en Amérique, Bull. Soc. géol. de France, Seance, de Fev. 4, 1861, p. 320), Sir William, nevertheless, said only that the shales and limestones of Quebec and Georgia are *subordinate to the Potsdam*—a formation which Dr. Emmons never claimed, though as we have seen, he consented to its inclusion in the Taconic.

† *Report of Progress from its Commencement to 1863.* Illustrated by 498 wood cuts in the text, and accompanied by an atlas of maps and sections. Montreal, 1863, 8-vo, pp. xxvii x 983.

"A great portion of the rock is fine grained, and the constituent minerals are arranged in parallel layers; no one constituent predominates in any layer, to the exclusion of others; but even in their subordinate arrangement, there is an observable tendency to parallelism. . . . There is a never-failing constancy in respect to their parallelism which, however, though never absent, is sometimes obscure." . . . Coarse-grained beds of the character designated "granitoid gneiss," "might, on first inspection, be mistaken for igneous, instead of altered sedimentary masses. Upon a careful study of any such mass, however, it will be perceived that this reticulated structure is accompanied by an obscure arrangement of the meshes of the net-work into parallel lines which will be found conformable with the more distinctly banded portion of the strata" (p. 23).

"The greatest masses appear to be formed of the coarse-grained porphyroidal gneiss above described. These rise into the highest ridges and peaks of the orthoclase region, and generally constitute the main body of rock separating one important band of limestone from another. . . . The quartz occasionally presents masses of considerable volume, two of which, nearly pure, occur in the district of the Rouge, a tributary of the Ottawa, one 400, and the other 600 feet thick. The hornblende often forms a massive rock; a band of it in Blythfield has a thickness of 200 feet. Mica, associated with hornblende and with quartz, characterizes great thicknesses of hornblende and micaceous schists."

"Though there does not appear to be any special order in which the masses succeed one another, beds of hornblende rock, and hornblendic schist seem often to be more abundant near the interstratified bands of limestone than elsewhere, and in the same neighborhood, there usually occurs a more frequent repetition of beds of quartzite than in other parts. Near the limestones, pyroxene, which in other parts does not appear to be very abundantly disseminated, is occasionally met with, forming massive beds" (p. 24).

The writer describes the distribution of garnets in the gneiss, and of its passage, in one instance, into garnetiferous quartzite. The masses of limestone are described, sometimes becoming interstratified dolomytes. Serpentine is found associated with both. Pyrallolite, or rensselaerite often accompanies limestone; and pyroxene and hornblende are sometimes found disseminated in grains or crystals. Tremolite forms beds in it. Mica and graphite are both generally present. Pyrites is more abundant. Other minerals are chondrodite, apatite, fluorite and oxides of iron. The gneiss is sometimes greatly contorted, but the beds of associated limestone, even when very thin, are conformable with the beds of gneiss, and parallel with those bands and streaks with which they are marked (p. 27). One instance has been noted "where the limestone of a bed marked with grains of serpentine, appeared to have an uninterrupted connection with rock of an identical character filling up a crack or fault in the gneiss, at right angles to the general direction of the strata" (p. 28).

In a section measured at the High Falls of the Madawaska, a tributary to the Ottawa, here presented as an average section, there are 48 alternations of beds, in a total thickness of 1351 feet. In these, limestones occur six times, giving an aggregate thickness of 46 feet; quartzyte occurs once, in a bed ten feet thick; and "schistose gneiss" occurs five times, giving an aggregate thickness of 116 feet. At a higher position in the series, is said to be a bed of limestone 100 feet thick. At the Chenaux, there is more limestone than gneiss—there being a thickness of over 400 feet, of which not one-fifth is intercalated gneiss; while in Clarendon, similar rocks reveal "a thickness of 4000 feet, about two-thirds of which consists of crystalline limestone" (p. 31).

Another phenomenon of collateral interest, is thus pointed out:

"Notwithstanding the general highly crystalline condition of the Laurentian rocks, beds of an unmistakably *conglomerate* character are occasionally met with among them. . . . On the twenty-fourth lot of the tenth range of Bastard, a bed of conglomerate is interstratified between two beds of limestone. The dip of the strata at the spot is 30°, N. 50° E." The following is a condensed section:

		Feet.	Inches.
7.	Limestone, white, coarse	6	
6.	Limestone, arenaceous, fine, very hard		4
5.	Sandstone, calcareous, fine		2
4.	*Conglomerate*, the matrix a fine grained, quartzose sandstone somewhat calcareous, with white feldspar in grains and pebbles. Pebbles flat, lying on their sides	1	6
3.	Quartzite, calcareous-granular, with calcite		2
2.	Quartzite, coarse, translucent-granular, with feldspar and limestone		4
1.	Limestone, white, coarse, with graphite and mica	5	

In Madoc, *conglomerate* occurs again, with calcareous matter; and in a higher position is a ridge "consisting of micaceous schists, beyond which, for 300 yards, ridges of a decided *conglomerate*, with distinctly rounded pebbles, enveloped in a matrix of micaceous schist, alternate with ridges of schist containing few or no pebbles."*

"Still farther north, another band of *conglomerate* occurs, associated with fine grained, soft, micaceo-silicious, feldspathic schist. The matrix of the conglomerate weathers white, and appears to be a dolomite. The pebbles, of which the largest may be six inches in diameter, are chiefly quartz, but there are also, pebbles or masses of feldspar, and a few of calc-spar. The quartz pebbles are for the most part, distinctly rounded, and their colors various, some being internally bluish, some white, and others pinkish. The feldspar is red and white, and the calcspar white. The dip of the rocks appears to be southward of east, but the slope is irregular, and may probably be 35° or 40°" (p. 33.)†

The anorthosite rocks are fully described. Their bedding is very obscure, but they occur in belts conformable with the limestones and the orthoclase gneisses. The hypersthene rock of northern New York, and of the Isle of Skye, are pronounced of the same character. Near Bay Saint Paul, is a mass of titaniferous iron ore in the anorthosite, 90 feet in width, by about 300 feet in length (p. 35.)

The following is a synopsis of a general section across a portion of the Laurentian (p. 45:)

		Feet.
10.	Anorthosite above the Morin limestone (conjectural)	10,000
9.	Orthoclase gneiss (and a band of quartz)	3,400
8.	Proctor's Lake limestone	20
7.	Orthoclase gneiss	1,580
6.	Grenville limestone	750
5.	Orthoclase gneiss	3,500
4.	Great Beaver Lake and Green Lake limestone	2,590
3.	Orthoclase gneiss	4,000
2.	Trembling Lake limestone	1,500
1.	Orthoclase gneiss of Trembling Mountain	5,000
		32,750

---

*Mr. Macfarlane subsequently describing these conglomerates, says they are "lithologically not unlike some of the Huronian rock." Whereupon, Sir W. E. Logan, in a note replies: "It is not to be inferred from the presence in them of a schistose conglomerate, that therefore, they are Huronian" (*Geology of Canada*, 1866, p. 93.)

†Sir William Logan never omits mention of these conglomerates, when having occasion to furnish a synopsis of the Laurentian. See, for instance, his announcement of organic traces (*Quar. Jour. Geol. Soc. Lond.*, Feb. 1865.)

In reference to the Huronian series, Sir William Logan makes statements from which the following extracts are drawn (p. 90:)

"On Lake Temiscaming, the Laurentian orthoclase gneiss is followed by a slate conglomerate. The finer parts of the rock are dark gray, weathering to dark green; they are of a uniform grain, and, being at the same time, argillaceous and silicious, they present the characters of a hard compact slate. Some parts not so fine in texture, are a hard, dark gray sandstone weathering to a dingy olive green. In both cases, the rock frequently exhibits the character of a compact conglomerate, holding pebbles and bowlders, sometimes a foot in diamater, of the subjacent gneiss, from which they appear to be principally derived."*

Some other conditions of the formation are described as finer textured, penciled in transverse fracture by fine colored lines; another as a "very close grained, compact, dark gray mica slate. When cleavage exists, the planes cut the pebbles in common with the matrix." It is never fit for roofing slates. To this slate conglomerate succeeds a quartzyte, apparently 400 to 500 feet thick.

"On the Sturgeon, Wahnapitæ and Whitefish rivers, there is usually interposed between the Laurentian gneiss and the recognized Huronian rocks, a mass of rather coarse grained greenstone or diorite."

The general section in the region of these three rivers, northeast of lake Huron, and stretching to lake Wahnapitæ—is represented by the following abstract (p. 52):

5. Quartzite, white and greenish, with beds of quartz conglomerate.
4. Slate conglomerate.
3. Limestone, much shattered and disturbed.
2. Slate conglomerate.
1. Silicious strata, fine grained, with greenish quartzite interstratified.

In the region nearer lake Huron, and along the northern shore westward, lies the typical part of the Huronian. As to its relations with the Laurentian, we have from the Canadian geologists, only the following information (p. 55):

"On the coast line, between the Mississagui and the Thessalon rivers, a distance of about 25 miles, the gneiss extends from within about four miles of the former, to within about the same distance of the latter; but, it is very much disturbed by intrusive granite and greenstone, and although there are great exposures of rock, it is very difficult to make out how the stratified portions are related to one another. The gneiss extends to the vicinity of a small stream, about a mile and a half above Les Grandes Sables, and what is supposed to be the lowest Huronian mass of that part, occurs about half a mile above the stream. It consists of a gray quartzite which *abuts against one mass of gneiss and runs under another*, and appears to be much broken by, and entangled among, the intrusive rock; but judging from a transverse measure in one part, its thickness would not be far from 500 feet. Farther west, after passing an exposure of stratified amygdaloidal trap, which would apparently overlie the [this] quartzite, the rocks for about two miles east of the Thessalon, appear to consist of green, fine grained chloritic and epidotic slate ["diabase slate"] alternating with masses that have the aspect of trap."

---

*But it will be remembered that no contact between these so-called conglomerates and the older gneisses had been observed: nor has it to this day. Nor, if such observation had been made, would the circumstance prove these "conglomerates" in immediate chronological succession to the gneiss. Palæozoic limestones were frequently observed resting on gneiss, in the progress of the Canadian survey. The pebbles in this conglomerate may have been derived from the gneiss, and laid down on the gneiss, after the interposition of the events of a geologic age of land history.

The following is an abstract of the general section in this region (pp. 55–7):

		Feet.
13.	White quartzite	400
12.	Yellowish chert and impure limestone	200
11.	White quartzite, frequently vitreous	1,500
10.	Yellowish chert, with thin and very regular beds	400
9.	White quartzite, frequently vitreous	2,970
8.	Red jasper conglomerates. Sometimes fine white quartzite. Greenstones intercalated	2,150
7.	Red quartzite with interstratified greenstones	2,300
6.	Slate conglomerate with interstratified greenstones	3,000
5.	Limestone, compact, green, drab or gray, thin bedded	300
4.	Slate conglomerate [as previously described]	1,280
3.	White quartzite, sometimes pebbly	1,000
2.	Chloritic and epidotic slates [probably eruptive]	2,000
1.	Gray quartzite, thickness doubtful	500
		18,000

It will be desirable to contemplate the above section separately from the section of "Huronian" rocks reported from the north shore of lake Superior. It is quite possible that the two sections relate to rocks belonging to different geological ages.

"On lake Superior, the Laurentian gneiss is succeeded by slates generally of a dark green without, and often of dark gray in fresh fracture, which at the base appear occasionally to be interstratified with beds of a feldspathic character, of the reddish color belonging to the subjacent gneiss. Sometimes these beds are a combination of feldspar and quartz, occasionally with the addition of hornblende and, in some of the beds, the hornblende predominating, gives them a general green color. Some of the beds have the character of diorite; others, that of mica slate, and a few present that of quartzite" (p. 52).

These seem to be identical with the lowest rocks of the iron-bearing series of Vermilion lake, a part of Lawson's Keewatin. They exhibit the well-known transition from Laurentian gneiss to crystalline schists. The mica schist is "nascent."

"Rising in the series, the dark green slates become interstratified with layers holding a sufficient number of pebbles of different kinds, to constitute *conglomerates*. The pebbles appear to be all derived from altered rocks; they greatly vary in size in different places, and occasionally measure a foot in diameter. Where the *slate conglomerates* have been worn by the action of water, the pebbles are generally worn down equally with the rest of the surface; and though a very distinct picture of them is presented on such a surface, where the water or weather appears to have had an influence in bringing out a well defined contrast in colors between the pebbles and the slate, at the same time producing a contrast between parallel bands of the slate on the terminal edges of the laminæ, it yet often happens, unless the pebbles are of white quartz, that they are very obscurely distinguishable on fracturing the rock — both the pebbles and the matrix having a gray color, and showing very little apparent difference in mineral character. On some of these pictured surfaces, small opaque, white feldspathic crystals occasionally spot the whole surface of the rock — the pebbles equally with the slaty matrix. The rock has nowhere on the lake been observed to display true slaty cleavage, independent of the bedding; but it often exhibits a jointed structure, and the divisional planes cut through the pebbles without the smallest deflection."* (pp. 52 and 53).

It is impossible to identify this description with the description of the Huronian rocks north of lake Huron. There are some circumstances which readily explain the course taken by the Canadian geologists, but the identification made as early as 1848, has perpetuated misconceptions, and bred unintelligible confusion. I have some confidence that we may be near the solution of the puzzle.

---

*The whole of the above description applies exactly to the lower part of the "Ogishke Conglomerate," on the shores of Ogishke Muncie or Kingfisher lake, in Minnesota, eighty miles west of Thunder bay. I shall return in the sequel, to a discussion of this identification. The stratigraphical position of the "Ogishke Conglomerate" has been in doubt; but if this parallelism is correct, it belongs near the bottom of the Vermilion lake iron-bearing schists.

The same basal slaty conglomerate occurs at other points along the north shore.

"A considerable thickness of these conglomerate or pebbly slates, is exposed at the mouth of the river Doré, near Gros Cap, about five miles above the mouth of the Michipicoten river. The strike of the rock is very regular, being about east and west, while the dip is highly inclined, the beds being not more than from ten to fifteen degrees from a vertical attitude; but the slope is for part of the distance, to the north, and for the remainder, to the south; there is not, however, supposed to be any repetition of the measures, which are given in descending order" (p. 53).

		Feet.
21.	Green slate rock, with a few scattered pebbles through some parts of it, in other parts conglomeratic; the sedimentary layers not distinctly marked; rock with a jointed structure; joints cutting straight through the pebbles.	40
20.	Green pebbly slate; edges of laminæ well marked, producing a ribboned appearance; pebbles chiefly gneiss, granite or syenite	300
19.	Green slate rock similar to 20 and 21	550
18.	Green pebbly slate	170
17.	Measures covered by sand	90
16.	Green slaty conglomerate, with large pebbles of igneous or altered rock	15
15.	Green slate rock with many pebbles	30
14.	Green slate with finer pebbles	40
13.	Green slate rock, with scattered, large pebbles	10
12.	Green slate rock, like 13	130
11.	Green slate conglomerate, with boulders sometimes a foot in diameter, in a slaty matrix	5
10.	Measures concealed by sand	30
9.	Green slate rock with many pebbles	80
8.	Green slate rock with pebbles	80
7.	Measures concealed by sand	20
6.	Green slate rock, very pebbly, sedimentary layers finely waved, water worn surface much pitted	30
5.	Green slate rock, bedding very even, appears to be somewhat talcose toward the top	20
4.	Green slate rock like 5	15
3.	Green slate rock with even bedding, slightly unctuous and talcoid in several of the divisions	20
2.	Green slate rock, a few scattered pebbles in parts, flattened in direction of the strata	90
1.	Green slate rock with large pebbles and small boulders of granite or gneiss, quartz and a chert-like stone (p. 54)	35
		1,700

The foregoing section is almost a continuous "slate conglomerate," or pebbly slate, and but for the so-called "talcose" matter, might hastily be identified with the slate conglomerate of the Thessalon valley. But, as will be shown, it is a different slate. The descriptions again apply to the Ogishke conglomerate. In Minnesota, this conglomerate is only one member of the iron-bearing series. In accordance with that fact, Sir William Logan adds:

"At the Doré, a much larger amount of the slate formation than is here given comes in behind the preceding section; but it was so covered with trees and moss, at the time of the examination, that it was found impossible to follow out the details. Toward the lower part, it *assumes more the character of the gneiss* which usually succeeds it, and becomes *interstratified* with reddish-yellow feldspathic layers; but sufficient data have not yet been ascertained to determine what may be the total thickness of the slate rock in this part, though it must probably attain several thousand feet" (p. 54).

Other localities on lake Superior where slate conglomerates and jasper conglomerates occupy a similar position, are between the Goulais river and Batchewahnung bay. The same seem to extend along the shore of the Michipicoten river, on each side, eight or nine miles. It occurs also, a little farther west on the coast, and again about five miles south of Otter Head (p. 63).

"Another locality is Thunder bay, where they occupy the coast for a distance of ten miles, immediately below the mouth of the Kaministiquia river, on the north side, leaning in a narrow strip against the gneiss of the lower series. It is not improbable that they may present a narrow belt in the valley of the Kaministiquia They occupy the coast for about seven miles on each side of the New Pic river; while an interval from this to a point two miles beyond the Old Pic river, including the coast of Peninsula Bay and Harbor, and Pic island, is composed of trap. Beyond this, the chloritic slates occupy about fifteen miles of the coast, extending to the neighborhood of the deep cove which receives the Pike river" (p. 64).

A characteristic feature of the Keewatin iron-bearing series is indicated in the description of the junction of these rocks with the gneiss on the Kaministiquia river, in the vicinity of the Grand Falls:

"At the lower end of the portage, where the series makes its appearance, the rock resembles a massive syenite, in some parts red, and in others, whitish, but is probably a hornblendic gneiss in which the lamellar arrangement of the constituent minerals is obscure, as the rock gradually passes into such a gneiss. Resting on it *conformably*, there occurs a series of dark greenish blue, or greenish black slates, the one rock *passing almost imperceptibly into the other*. . . At each rapid part of the river above the Grand Falls, there is a greater or less development of these rocks, most frequently presenting the more distinctly stratified part of the gneiss. The best exposure of the slate is at the Three Discharges, about four miles above the Grand Falls, where the rocks are observed to pass from the gneiss to the slate." The vertical thickness at this place is about 2,300 feet.

"Toward the bottom, near the junction with the gneiss, the slates are of a bluish and occasionally of a brownish color. They are intersected by numerous parallel joints which divide the mass into rhomboidal forms of singular regularity. The middle and upper portions of the section are usually of a pistachio green, resembling the green of epidote, and frequently in part present a jaspery character. They are hard and compact, usually with a conchoidal, but sometimes with a splintery fracture. The divisional planes are frequently covered with mica, and in such cases, the rock may almost be termed a mica slate" (p. 65). Similar rocks continue as far as Dog lake.

The foregoing description applies perfectly to the passage from the iron-bearing formation to the gneisses, as observed in a hundred places in northeastern Minnesota. No structural unconformity exists, as a fact of present observation. It is not intended to assert, however, that it never existed.

The schists observed along the north shore of lake Huron, in which the Bruce and Wellington and Wallace mines were worked, constitute Logan's "Lower Copper-bearing series." As these were identified with the series of slates just described, they were also made to represent the Lower Copper-bearing series. Neither series could be identified with the copper rocks of the south shore of lake Superior. But as those rocks were observed on the north shore at a higher stratigraphic level, they were demoninated by Logan the "Upper Copper-bearing rocks." But in thus fixing parallelisms, he strangely overlooked the importance of a series between the proper Cupriferous rocks above and the pseudo-Cupriferous rocks below. These were the real Lower Copper-bearing rocks, though Logan joined them to the Upper, or south shore Cupriferous. His treatment of the so-called "Upper Cupriferous rocks" will appear from a few extracts.

"The Huronian formation of Lake Superior [the real iron-bearing series] is *unconformably* overlaid by a second series of copper-bearing rocks, which may be conveniently divided into two groups. Of these the lower consists of bluish slates or shales interstratified with sandstones and beds of columnar trap; and the upper, of a succession of sandstones, limestones, indurated marls and conglomerates, also interstratified with trap which is often amygdaloidal" (p. 67).

The following is a characterization of the lower group of the Upper Copper-bearing series, (p. 67):

"The base of the formation where seen in Thunder Bay, in contact with the subjacent green slates or slate conglomerates, presents conglomerate beds probably of no great thickness, composed chiefly of quartz pebbles, with a few of red jasper, and some of greenish, chloritic slate, in a greenish, arenaceous matrix, consisting of the same materials in a finer condition. These are followed by a set of very regular, even layers of chert, sometimes approaching a chalcedony, varying in color from nearly white, through different shades of gray to black, and in thickness, from less than half an inch to six inches, and even a foot. These are separated from one another by thin layers of dark gray dolomite, weathering rusty-red and present a striking ribbon-like appearance. Occasionally, thicker beds of dolomite occur, sometimes highly crystalline, separating aggregated bands of the ribbon-like strata; and these dolomitic beds, as well as the chert bands, are sometimes interstratified with argillaceous layers" (p. 67).

"In the vicinity of disturbed parts, the chert sometimes passes into chalcedony and agate, and small cracks are filled with what appears to be anthracite. Some of the chert bands appear to be made up of a multitude of minute, irregular, closely aggregated, sub-globular bodies, floating as it were, in the silicious matrix. Anthracite seems to be present in the centre of some of these, leading to the supposition that the color of the black chert, even where these shapes are not detected, may be owing to the presence of carbon. In some parts of these oölitic chert layers, small blood-red jasper spots occasionally become interstratified with the black. . . .

"Higher in the formation, argillaceous slates become interstratified with argillaceous sandstones in such an ealterd condition that it is often difficult, at first sight, to say whether the latter may not be trap layers. . . In some parts of the vertical thickness, calcareous layers are occasionally interstratified among the slates, but few of them are pure enough to be entitled to the appellation of limestones. . . "On the Kaministiquia, the lowest part of the formation occurs near Grand Falls. Its immediate junction with the rock on which it rests is concealed from view. . . The argillaceous strata visibly reach to within a short distance of the pond [in which the junction is supposed to occur] (p. 68).

"The general color of the rock is here black, weathering to a rusty brown. Some of the beds being soft and shaly, are easily decomposed by atmospheric influences, while the mass is, for the most part, a hard argillaceous slate. The whole formation appears to be more or less calcareous, and among the lower members, thin beds of magnesian limestone occur, sometimes alternating with thin beds of black chert" (p 68–9).

"In Thunder bay, and on the coast above it, trap bands, conformable with the stratification, are interstratified in several parts of the formation, but they occur in greatest thickness toward the bottom, not far above the chert-beds, and at the summit, overlying the whole of the mass. . . In all cases, the trap presents a very striking sub-columnar structure at right-angles to the plane of the stratification; and the crowning overflow gives a peculiar aspect to the whole region occupied by the formation to which it belongs. The overflow is from 200 to 300 feet thick, and the whole of the associated rocks, to the base of the formation, may possess a volume of between 1,500 and 2,000 feet." (pp. 69, 70).

The foregoing is a good description of the black slates and the slate-conglomerate of the so-called Huronian series north of lake Huron. In the latter region, columnar trap (or gabbro) does not constitute a persistent "crowning overflow", as far as the descriptions given by the survey indicate, but interbedded traps are present, and the lithological characters of the formation—the black shale, the cherty and flinty layers, the oölitic structure, the even beds, the proximate horizontality—and no other known formation about lake Superior presents any close resemblance to the Huronian strata. These black slates of Thunder bay, moreover, are now known to extend westward into Minnesota, and to overlie unconformably a mass of vertical, sub-crystalline schists in the same manner as at Thunder bay.

As to the upper group of the Upper Copper-bearing series, little needs to be said here, as this is the well known Cupriferous series of the south shore, consisting chiefly of intercalated beds of sandstone, conglomerate and trap, with occasional beds of limestone, and attaining an aggregate thickness of 6,000 to 10,000 feet. The trap is often amygdaloidal, and native copper occurs in irregular grains and strings and masses up to ten pounds in weight. Sir William Logan's discussion of this formation does not possess theoretical significance.

In an appendix to the report of 1863, Sir William Logan states that "the Taconic system of Emmons, which he supposed to be a distinct series of rocks more ancient than the Potsdam, appears to consist, for the greater part at least, of the strata of the Potsdam and Quebec groups. The Upper Copper-bearing rocks of lake Superior are regarded as occupying the position of the Quebec group, to which they bear some resemblance in lithological and mineralogical characters. They may, perhaps, include the Potsdam group."* [Compare the views of Foster and Whitney.]

The following is a summary of Sir William Logan's successive views on the classification of the Azoic rocks of Canada:

<table>
<tr><th colspan="5">DIVISIONS OF ARCHÆAN ROCKS RECOGNIZED BY LOGAN.</th><th>PUBLICATION.</th></tr>
<tr><td colspan="5">Metamorphic Series.</td><td>1845.</td></tr>
<tr><td colspan="2">Lower Group.</td><td colspan="3">Upper Group (Lake Sup).</td><td>1846.</td></tr>
<tr><td colspan="2">Gneiss, Mica slate.</td><td colspan="3">Quartz rock, etc.</td><td>1847.</td></tr>
<tr><td colspan="5">Granitic or Metamorphic Group.</td><td>(1848) 1850.</td></tr>
<tr><td colspan="5">Metamorphic or Gneissoid Group.</td><td>(1849) 1850.</td></tr>
<tr><td colspan="5">Metamorphic Group.</td><td>1851.</td></tr>
<tr><td colspan="2">Gneiss, etc.</td><td colspan="3">Cambrian.</td><td>(1851) 1852.</td></tr>
<tr><td colspan="5">Laurentian Series.</td><td>(1852) 1854.</td></tr>
<tr><td colspan="2">Laurentian Formation.</td><td colspan="3">Huronian Series (Murray).</td><td>(1853-7) 1857.</td></tr>
<tr><td>Laurentian</td><td>Upper Laurentian, or Labradorian.</td><td colspan="3">Huronian.</td><td>1857.</td></tr>
<tr><td colspan="2">Laurentian.</td><td>Huronian. (Lower Copper bearing rocks.)</td><td colspan="2">Upper Copper-bearing rocks.</td><td>(1863).</td></tr>
<tr><td colspan="2" rowspan="3">Laurentian Series.</td><td rowspan="3">Huronian Series.</td><td colspan="2">Upper Copper-bearing rocks.</td><td rowspan="3">1866.</td></tr>
<tr><td colspan="2">(Quebec group)</td></tr>
<tr><td>Lower group</td><td>Upper group</td></tr>
</table>

NOTE.—Dates of presentation of reports are placed in parentheses.

One of the important features of the volume on the Geology of Canada, 1863, was the introduction of the "Quebec Group," supposed to be a group of strata occupying a position between the characteristic part of the Calciferous and the Hudson River shales, and specially investigated in the vicinity of Quebec. Sir William Logan was so good a physical geologist that when he had given his sanction to the proposal, a strong predisposition was given to American opinion. Thus the Quebec group had the sanction of James Hall, E. Billings and T. S. Hunt, and found admission to the second edition of Dana's "Manual of Geology." We have seen, however, what misgivings on the subject were entertained by professor Hall, and how he permitted his respect for Sir William Logan to compromise his own palæontological convictions. The "Group" remained a stumbling-block and an enigma in American geology until, failing in prestige during the last decade, it received its final *coup de grace* at the hands of the Survey itself, in 1889.†

---

*Geology of Canada, 1863, p. 934.

†Second Report on the Geology of a portion of the Province of Quebec. R. W. Ells. *Geol. Sur. Canada, Annual Report.* 1887-88. Montreal 1889.

It would be profitless to pursue the history of an opinion which has already lost its hold on credence, even if were the purpose of the present memoir to deal with discussions exclusively palæontological. But the rocks have been, in some regions, so confounded with those of the so-styled Taconic, that the investigation of the latter involves a review of opinion on the former. For the convenience of the student, therefore, the titles of the principal papers bearing on the discussion, are here appended*

---

*1861. Logan, Sir W. E.
In "Correspondence of Joachim Barrande, Sir William Logan and James Hall, on the Taconic System, and the Age of the Fossils found in the Rock of northern New England and the Quebec Group of Rocks." *Amer. Jour. Sci.* II, xxxi. 210-226.
1862. Logan, W. E.
Determination of Age of Quebec Rocks. *Amer. Jour. Sci.*, II, xxxiii, 105-6.
1862. Logan, W. E.
Considerations relating to the Quebec Group and the Upper Copper-bearing Rocks of Lake Superior (Read before Montreal Nat. Hist. Soc.), *Amer. Jour. Sci.*, II, xxxiii, 320-327.
1863. Logan, W. E.
The Quebec Group. *Geology of Canada*, 1863, pp. 225-397.
1863. Logan, Sir W. E.
Letter addressed to Mr. Joachim Barrande, on the Quebec Group at Point Lévis, Montreal, pp. 1-14. Reprinted, *Amer. Jour. Sci.*, II, xxxvi, 366-377.
1866. Logan, Sir W. E.
The Quebec Group and its Divisions. *Canada Report*, 1863-6, pp. 4-6.
1866. Richardson, James.
Divisions of the Quebec Group. *Canad. Rep.*, 1863-6, pp. 29-34.
1870. Richardson, James.
Report on the South Shore below Quebec [Rocks of the Quebec Group]. *Canad. Rep.*, 1866-1869, pp. 119-149.
1873. Selwyn, A. R. C.
Note of a Preliminary Geological Reconnoissance from Lake Superior by the English and Winnipeg rivers to Fort Garry [Comparèd with Quebec]. *Canad. Rep.* for 1872-3, pp. 8-18.
1879. Selwyn, A. R. C.
Report of Observations on the Stratigraphy of the Quebec Group and the Older Crystalline Rocks of Canada. *Canad. Rep.*, 1877-8, A, pp. 1-15.
1883. Adams, Frank D.
Notes on the Microscopic Structure of some Rocks of the Quebec Group. *Canad. Rep.*, 1880-82, A, pp. 8-23.
1887. Ells, R. W.
Report on the Geology of a portion of the Eastern Townships of Quebec. *Canad. Rep.* 2d Ser. Vol. II, 1866, J, pp. 1-70.
1888. Ells, R. W.
Second Report on the Geology of a portion of the Province of Quebec. *Canad. Rep.* 1887-8, Vol. III, Pt. I. K, pp. 1-120.
1890. Ells, R. W.
The Stratigraphy of the Quebec Group *Bull. Geol. Soc. Amer.*, I. 453-468.
1890. Brainerd, Ezra and Henry M. Seely.
The Calciferous Formation in the Champlain Valley. With a Supplement on the Fort Cassin Rocks and their Fauna, By R. P. Whitfield. *Bull. Geol. Soc. Amer.*, I, 501-516.
1890. Walcott, C. D.
A review of Dr. R. W. Ells' Second Report on the Geology of a Portion of the Province of Quebec, with Additional Notes on the "Quebec Group." [History of Views] *Amer. Jour. Sci.*, III., xxxix, 101-115.
1890. Hunt, T. Sterry.
The Geological History of the Quebec Group. *American Geologist*, Vol. iv, p. 212.

See, also, the references on the Taconic System, many of which bear on the Quebec Group,

JOSIAH D. WHITNEY.

1847. Josiah D. Whitney and Joseph W. Foster were assistants, in 1847, of Dr. C. T. Jackson in his survey of the "mineral lands" of lake Superior; and Mr. Whitney continued in the same capacity in 1848. In 1849 and 1850, Messrs. Foster and Whitney succeeded Dr. Jackson, and their Annual Report is dated Boston, Nov. 5, 1849. Mr. Whitney's observations in 1847, were restricted to the copper-bearing rocks, mostly of the Ontonagon district, and he had no occasion to introduce general views in his report; but a part of Mr. Foster's notes relate to a traverse from lake Superior over the Menominee region, to Green bay.[*] Mr. Whitney does not appear to have transmitted to Dr. Jackson, anything except barometric observations as the result of work in 1848 (*op. cit.*, pp. 644-646).

1849. In their report of 1849, Messrs. Foster and Whitney say: Experience "has demonstrated that the veins of copper and its ores in the sandstone and conglomerate are not to be relied on, and that when worked even to an inconsiderable depth, they give out. . . All the productive lodes are confined to the ranges of trap. . . The associated sandstone and conglomerate belong to the Silurian system, and rest at the base of all the fossiliferous rocks" (p. 607.)[†] Accompanying this report are four geological maps: 1. Ile Royale; 2. Keweenaw Point; 3. The district between Keweenaw Bay and Chocolate River; 4. The district between Portage Lake and Montreal River. On the 3d and 4th of these Maps, the term "Azoic" is introduced. The 4th Map was transmitted to the Secretary of the Interior by a letter dated July 25th, 1849. The date of transmittal of the other is not known, but probably, the same month. On the 3d Map, the explanatory legend presents the following arrangement:

Aqueous,	Base of the Silurian System,	Sandstone.
Metamorphic,	Azoic System,	Quartz. Saccharoidal limestone Schistose Rocks.

---

[*] The Report is found on pp. 773-784 of that chaos of literary, scientific and statistical matter called Jackson's Geological Report, occupying pages 371-801 of "*Annual Message and Documents*," 1849-50, Part III—except pages 605-624, including four maps, occupied by Foster and Whitney's report for 1849, which is interjected into the midst of Jackson's report.

[†] Dr. Jackson, (*op. cit.* p. 399), says "Anterior to my researches, the red sandstones of Lake Superior were supposed to be the "old red," and subsequently the opinion that they belonged to the Potsdam, N. Y., series, gained ground; but, from the facts that the mineral composition, associations and contents were identical with the sandstones of Nova Scotia, Connecticut, Massachusetts and New Jersey, and that the disturbing agency which moved them was in the same direction and produced similar, if not identical results, I was disposed to regard those rocks as of the same age, or as of the New Red sandstone series. This idea has been confirmed."

Igneous Formation,	More recent than the Azoic, but older than the Silurian,	Trappean Rocks. Granite. Basalt.

The legend on the 4th Map is as follows:

Aqueous Formation,	Lower Silurian System.	Lower Magnesian Limestone. Sandstone. Conglomerate.
Metamorphic,	Azoic System,	Schistose Rocks.
Igneous,	Contemporaneous with Silurian,	Trap. Jasper and Quartzose Porphyry.
	More recent than Azoic,	Granite.

1850. The first part of the final report, relating to the "Copper Lands," was transmitted April 15, 1850.[*] In the IVth chapter, the authors, treating of "Stratified and Sedimentary rocks," comprise them under three general divisions:

III. Compact or Lower Magnesian Limestones. 3. Birdseye and Black river limestone; 2. Chazy limestone; 1. Calciferous sandstone.

II. Inferior Sandstone. Potsdam Sandstone.

I. Conglomerate. Not strictly a sedimentary rock, but a volcanic tuff.

Speaking more particularly of the conglomerates, the authors state concerning the pebbles: "Their surfaces do not present that smooth, polished appearance which results from the attrition of water,[†] in fact, a close observer can readily distinguish between those which have been recently detached from the rock and those which have been for a time exposed to the recent action of the surf. The conglomerate appears to have been formed too rapidly to suppose that the masses were detached and rounded by the action of waves and currents, and deposited with silt and sand on the floor of the ancient ocean; for while the contemporaneous sandstone remote from the line of volcanic foci, does not exceed three hundred or four hundred feet in thickness, the united thickness of the conglomerate bands, in the vicinity of the trappean range on Keweenaw Point, exceeds five thousand feet. As we recede for a few miles from the line of the volcanic fissure, these amygdaloidal pebbles disappear, and are replaced by arenaceous and argillaceous particles. We are therefore disposed to adopt the theory as to the origin of such masses first suggested by Von Buch: 'When basaltic islands and trachytic rocks rise in fissures, friction of the elevated rock against the walls of the fissures, causes the elevated rock to be enclosed by conglomerates composed of its own matter. The granites composing the sandstones of many formations have been separated rather by friction against the erupted volcanic rock than destroyed by the erosive force of a neighboring sea. The existence of these friction conglomerates, which are met with in enormous masses in both hemispheres, testifies to the intensity of the force with which the erupted rocks have been propelled from the interior through the earth's crust. The detritus has suddenly been taken up by the waters, which have then deposited it in the strata which it still covers'.* Those pebbles having a highly vesicular structure may have been ejected through the fissures in the form of scoriæ while in a plastic state, and have received their rounded shape from having been projected through water—on the same principles as melted lead when dropped from an elevation assumes a globular form '.†

---

[*] *Report on the Geology and Topography of a Portion of the Lake Superior Land District in the State of Michigan.* By J. W. Foster and J. D. Whitney, United States Geologists. In two parts. Part I. Copper Lands. Washington, 1850, 8vo, pp. 224, with a Map and xii Plates. (Being *Ex. Doc.* No. 69, House of Representatives, 31st Cong, 1st Sess.)

[†] The "attrition" which rounds shore pebbles is not "attrition of water". Perhaps the authors mean attrition *in* water.

On page 112, in a note, the authors cite similar conglomerates of eruptive origin, in the Hawaiian and Fiji islands, as described in the report by professor Dana, on the Geology of the Exploring Expedition.

In speaking of the sandstone, they do not, like Houghton, discriminate between that which is interbedded with conglomerate layers, and that which overlies both, though they recognize, as Houghton did, the synclinal arrangement of the beds forming the lake basin, and give a theoretical diagram illustrating it. They say: "During the deposition of the sandstone, numerous sheets of trap were ejected and flowed like lava streams, and the igneous and aqueous products were so intermingled as to present the appearance of having been derived from a common origin." (p. 110.) The general discussion, however, relates to that which Houghton had denominated "Lower or Red Sandstone."

The method of geologic action which gave origin to the Cupriferous formation is conceived by the authors as follows: The entire region was the bed of an ocean of heated waters, and volcanic paroxysms were frequent. Numerous fissures through the crust of the earth resulted. "Along the lines of these fissures existed numerous volcanic vents, like those observed at this day in Peru, Granada and Java, which were characterized by periods of activity and repose. From these vents were poured forth numerous sheets of trap, which flowed over the sheets of sand and clays then in progress of accumulation. During the throes and convulsions of the mass, portions of rock would become detached, and rounded simply by the effects of attrition, and jets of melted matter be projected as volcanic bombs through the air or water, which on cooling would assume spheroidal forms, while other portions of the rock, in a state of mechanical division, would be ejected in the form of ashes and sand, which mingling with the water, would be deposited, as the oscillations subsided, among the sand and pebbles at the bottom of the sea. During the whole of this period of volcanic activity, the sands which now form the base of the Silurian system were in progress of accumulation, and became mingled with these igneous products" (p. 120). "Thus, alternating bands of igneous and aqueous rocks were formed", and thus, unlike the theory of Dr. Houghton, which regarded the trap sheets as dykes, our authors contemplate them as overflows.

---

*Geognostische Briefe, S. 75-82.

†Report on Copper Lands, pp. 99, 100.

1851. The second part of Foster and Whitney's report on the Mineral Lands of Lake Superior* was transmitted to the secretary of the Senate, November 20, 1851. It is a comprehensive, thorough and scientific presentation and discussion of the general and economic geology of the region embraced — with the exception of matters treated in Part I. It is probably the most meritorious production to that time issued under the auspices of the general government. The lithographed engravings are superior, but the wood-cuts are obscure, and the typography and paper cheap and unworthy. This volume has become celebrated as the one in which the "Azoic System" was established in America.

In the preliminary chapter, a general classification of the rocks of the district is given, of which the following is the lower part :†

Aqueous.	Silurian System.	Potdsam Sandstone,‡ etc.	
Metamorphic.	Azoic System.	Beds of Quartz and Saccharoidal Marble. Chloritic, Talcose and Argillaceous Slates Gneiss, Mica and Hornblende Slate.	
Igneous.	Of various ages.	Trappean volcanic rocks.	Masses of Specular and Magnetic Oxide Iron. Hornblende and Serpentine rocks. Basalt, Amygdaloid. Greenstone or Dolerite Porphyry.
		Plutonic rocks.	Feldspar and Quartz rock. Syenite. Granite.

"Below all the fossiliferous groups of this region" say the authors, "there is a class of rocks consisting of various crystalline

---

[*] *Report on the Geology of the Lake Superior Land District.* By J. W. Foster and J. D. Whitney, United States Geologists. Part II. The Iron Region, together with the General Geology, March 13, 1851: Ordered to be printed, Washington, 1851 [8-vo., pp. 406, 36 plates of illustrations, and a geological map of the upper Peninsula of Michigan and of the north shore of lake Superior from Sturgeon bay eastward.]

[†] It will be remembered that in all the stratigraphic tables of the present memoir, the older rocks stand below. This is an inversion of the arrangement adopted by Foster and Whitney, and most of the earlier writers.

[‡] The age of the Potsdam sandstone was discussed by the authors in *Proc. Amer. Assoc.*, Cincinnati meeting, 1851. (pp. 22-38).

schists, beds of quartz, and saccharoidal marble, more or less metamorphosed, which we denominate the Azoic system. This term was first applied by Murchison and De Verneuil* to designate those crystalline masses which preceded the Palæozoic strata. In it, they include not only gneiss, but the granitic and plutonic rocks by which it has been invaded. We adopt the term but limit its signification to those rocks which were detrital in their origin, and which were supposed to have been formed before the dawn of organized existence.†

Obviously, there is a degree of indefiniteness about this definition: 1st. Remains of organization may be found in rocks which "preceded the Palæozoic" as understood by Murchison: 2d. Not only gneiss but granite and syenite may yet be proven of detrital origin. Thus the base of the Palæozoic may be lowered either by the discovery of fossiliferous rocks between the Potsdam and the top of the Azoic as known to Foster and Whitney, or by the discovery of fossils within the Azoic rocks as thus known; and the base of the Azoic may be raised by the demonstration of the original igneous condition of the gneisses, or lowered by the demonstration of the original sedimentary condition of the granitoid masses. These, however, are only practical difficulties in the application of the conception of Foster and Whitney. The conception as above defined is clearly delimited and rational. By a reasonable application of the conception, the Azoic system would always embrace the strata beneath the oldest at any time found to be fossiliferous‡ and above the rocks at any time held to be igneous in origin. This was very nearly Emmons' first conception of the Taconic, nine years earlier; but he recognized the Potsdam sandstone as the base of the Silurian system, and only by provisional inference, the base of the Palæozoic series so that when strata older than the Potsdam were found fossiliferous, he changed his view in reference to the azoic character of the Taconic, and thereafter insisted that it was a zoic system.

"Most of these rocks [of the Azoic system,] the authors state, "appear to have been of detrital origin, but greatly transformed by long exposure to heat. They are sub-crystalline or compact in their structure, and rarely present unequivocal signs of stratification. They exhibit the most violent dislocations; in one place the beds are vertical, in another, reversed, and in another, present a succession of folded axes. Intermingled with them is a class of rocks whose igneous origin cannot be doubted, and to whose presence, the metamorphism so characteristic of this series, is in some measure to be ascribed. They consist of varying proportions of hornblende and feldspar, forming traps and basalts, or, where magnesia abounds, pass into serpentine rocks. They appear in some instances to have been protruded through the pre-existing strata, in the form of dikes or elvans, in others, to have flowed in broad lava streams over the ancient surface; and in others, to have risen up through some wide-spreading, expanding fissure, forming axes of elevation" (p. 8).

---

* *The Geology of Russia in Europe and the Ural Mountains*, vol. i, p. 10, 1845,. See also *Proc. Geol. Soc. Lond.*, vol. iv, p. 602, 1845.

†Foster and Whitney, *Rep.*, p. 3.

‡Mr. Whitney has indicated the possibility that the upper limit of the Azoic might have to be placed lower than the base of the Potsdam sandstone. "If we find in this country, a series of fossiliferous beds below those at present recognized, and whose organic contents cannot be considered as being of Lower Silurian type, let us give them a new name which shall not involve us in any Cambrian controversies." (*Amer. Jour. Sci.*, II, xxiii, p. 314).

"Many eminent geologists maintain that the lowest stratified rocks are but portions of the Silurian or Cambrian system; and that from long continued exposure to heat the lines of stratification have become obscure, and all traces of organic remains obliterated. Our investigations in this district have led us to a different conclusion. If the Potsdam sandstone rests at the base of the Palæozic series; if from that epoch we are to date the dawn of animal creation, there is in this district a class of obscurely stratified rocks interposed between the Silurian system and the granite—rocks distinct in character, unconformable in dip, and destitute of organic remains" (p. 10).

The authors quote from the early reports of "Mr. Logan, the distinguished Provincial geologist of Canada, for the purpose of stating that the two-fold division of these rocks, described by Mr. Logan[*] has not been observed on the southern shore.

In reference to the blending of igneous and sedimentary characters in the Azoic rocks of the south shore, the authors quote from de la Beche a passage which, though it possesses only the authority of an individual, needs to be borne in mind in the more recent attempts to interpret the rocks in question, whether on the south or the north shore. This is the passage:

"There is so intimate a mixture of compact and schistose trappean rocks with the argillaceous slates [of Bossiney, Cornwall] that the whole may be regarded as one system, the two kinds of trappean rocks having been probably erupted, one in a state of igneous fusion, and the other in that of an ash, during the time that the mud now forming slates, was deposited; the mixture being irregular from the irregular action of the respective causes which produced them, so that, as one may have been derived from igneous action, and the other from the ordinary abrasion of pre-existing solid rocks, they were geologically contemporaneous."

---

[*] *Report of Progress*, 1846-7, p. 10. It is clear that the upper division here indicated in the metamorphic rocks is what was afterward denominated *Animike*. But we shall return to this point. It is also apparent that this division, if not entirely wanting on the southern shore, is very inconspicuously developed.

Some further remarks by the authors relate specifically to the rocks on the south shore of lake Superior. "Many of the igneous rocks of this region form neither long lines of dykes nor axes of elevation, but broad sheets, bearing the same relation to the slates that the trappean bands of Keweenaw Point do to the conglomerates. Many of the slates appear to be composed of pulverulent greenstone, as though they might originally have been ejected as an ash, and subsequently deposited as a sediment, and pass by imperceptible gradations from a highly fissile, to a highly compact slate." Some of these phenomena are compared with sub-oceanic salses, "pouring forth streams of pulverulent material to be mingled with ordinary fragmental deposits.

Messrs. Foster and Whitney, in concluding their account of the general geology of the Azoic system, seek to strengthen its establishment by pointing out the existence of a similar series of rocks in other states—in Minnesota, Arkansas, Missouri, New York, Pennsylvania and Virginia. They refer to the evidence supplied by the brothers Rogers, that the series of obscurely stratified rocks known as the gneissoid series, flank the Appalachian chain on the east throughout its entire extent. Turning to the Old World, they cite the well known witnesses to the existence of similar azoic rocks in Scandinavia, Great Britian and Bohemia (pp. 33, 34.)

As to the origin of the mass of magnetic oxides of iron, having shown that they occur in beds instead of true veins, they consider the evidences of an igneous and of a metamorphic origin, and conclude: "On the whole, we are disposed to regard the specular and magnetic oxides of iron as a purely igneous product, in some instances poured out, but in others sublimed, from the interior of the earth. . . Where these ores occur in a state of almost absolute purity, in the form of vast irregular masses, occupying pre-existing depressions; or where the incumbent strata are metamorphosed and folded over them; or where they are traversed by long lines of ferruginous matter in the form of dykes—there can be little doubt that these ores have risen up in a plastic state from below.

"Where they are found impregnating metamorphic products, such as jasper, hornstone or chert, quartz, chlorite and talc slate, not only interposed between the laminæ, but intimately incorporated with the mass, giving it a banded structure, we regard it as the result of sublimation from the interior."

"When they are included in metamorphic strata, in the form of beds of variable width, with a conformable range and dip, and with minute particles of the associated rock mechanically mixed with the ore, we are disposed to regard them as the result of aqueous deposition, although the materials may have been derived from the ruins of purely igneous products" (p. 68.)

In *1857*, Sir William Logan and the Canadian geologists having recognized two distinct systems beneath the Potsdam sandstone, Mr. Whitney returned to the defence of the systemic unity of the sub-Silurian rocks, and of the system which he and Mr. Foster had proposed to receive them.[*] Mr. Whitney thinks this divergence of opinion is "due entirely to a different understanding of the origin and relations of the cupriferous formation of lake Superior and especially of that portion of it which belongs to the southern shore of the lake" (p. 306.) He proceeds accordingly, to establish the proposition that the cupriferous series of interbedded traps, conglomerates and sandstones are collectively the equivalent of the sandstone extending generally along the south shore. This being so, nothing remains between the cupriferous series and the granite except the indivisible series of rocks which Foster and Whitney had styled the Azoic system.

If we follow Mr. Logan, he says in effect, we must admit that the cupriferous belt lies unconformably beneath the sandstone.

"We must also admit that these cuperiferous rocks are identical in age with the series of quartz beds and jasper conglomerates displayed on the north shore of lake Huron, and hence called 'Huronian.' Therefore, according to Mr. Logan's views, since the cupriferous series of lake Superior rests unconformably on a still lower formation of shales, quartz rock, etc., the rocks of lake Huron must also do the same, although no such fact has been observed. Hence, we must recognize two systems beneath the Potsdam sandstone, one the Huronian, comprising the cupriferous rocks of lake Superior and the formations of the north shore of lake Huron, the other, the Laurentian, including all the rocks of Canada and the Northwest which we should designate by the term 'Azoic,' with the exception of those of lake Huron, as before indicated."

"The principal question to be settled then, is this: What are the relations of the cupriferous rocks of lake Superior? Do they constitute a distinct system by themselves, or are they part and parcel of the Potsdam sandstone itself?" And this is the question which Mr. Whitney proceeds to answer affirmatively. Mr. Whitney's two main positions as against those of Sir William Logan, may be stated thus:

---

[*] J. D. Whitney, "Remarks on the Huronian and Laurentian systems of the Canada Geological Survey," *Amer. Jour. Sci.*, II, 305-304, May, 1857.

1. The cupriferous formation is *not* distinct from the Potsdam.
2. The Huronian rocks are *not* equivalent to the cupriferous.

In *1884*, professor Whitney again returned to a vindication of the integrity of the Azoic system.* In an extended and elaborate memoir, Messrs. Whitney and Wadsworth review all that had been written in America on rocks embraced under the Azoic system. They pursue the method of liberal quotation, in setting forth the views of the various writers, and accompany these by critical remarks. The authors find very little to commend in this literature, but discover many opportunities for caustic comment, seeming almost to forget that possibly the honest search for truth may not lie, precisely in an adoption of the views of the originators of the Azoic system. Still there is a good amount of justice in the following sentence, extracted from their "Resume:"

"We think that it is impossible for any unprejudiced worker in this department of science to peruse with care the preceding pages, and not feel obliged to admit that the geology of a large portion of this country, and especially that of Canada and New England, is in an almost hopeless state of confusion. We thing that it must have been made clear to the candid mind, that the geologist would find himself completely baffled, who should endeavor to obtain any definite knowledge of the real nature and order of succession of the rocks which cover so large a portion of the region in question, from the study of that which has been published with regard to them. We believe that we are justified in going still farther, and saying, that our chances of our having, at some future time, a clear understanding of the geological structure of northeastern North America would be decidedly improved, if all that has been written about it were at once struck out of existence" (pp. 519-520.)

All this tends to prove, as the authors think, that no real progress has been made in azoic geology since 1850. Their impressive resumé embraces the following positions: *First*, No evidence has been presented of the existence of life anterior to the advent of the primordial fauna of Barrande—that is, in those metamorphic rocks which were at first united in a system styled "Azoic." The supposed organism known as *Eozoön*, is only a peculiar arrangement of crystalline matter. Its organic nature was never consistently defended by Dawson and Carpenter. The segregated, vein-like character of the limestones in which it occurs in eastern Massachusetts, has been affirmed by Burbank, Perry and Dr. Wadsworth, and the final *coup de grace* has been administered by Dr. Möbius. The epitaph has been written by F. Römer and Zittel. As to the organic origin of the crystalline *limestones*, there is nothing whatever to prove it, while the presene of calcite and calcitic formations in metalliferous veins, and in dykes and amygdaloids is sufficient proof that the existence of a limestone does not necessarily imply conditions compatible with organization. *Graphite*, too, instead of being a derivative of vegetable substances is found in the presence of indications of intense heat, and has never been found in such situation as to justify the inference that it resulted from the transformation of coal. As to the origin of masses of *magnetic and specular oxides of iron*, there is nothing in the laws of chemistry to forbid their eruptive nature, while the distribution of iron in meteorites and on the earth, and the evidences touching the mineral nature of the earth's interior, all tend to show the probability that the iron of the earliest times was connected with the agency of heat rather than of organization.

---

* *The Azoic System and its Proposed Subdivisions.* By J. D. Whitney and M. E. Wadsworth. *Bull. Mus. Comp.* Zoöl., Geological Series, vol. 1, pp. xvi and 331-565.

Secondly, As to the admissibility of a subdivision of the azoic rocks, the authors maintain that no adequate ground has yet been presented. They moreover, preclude the possibility of such ground by laying down the canon that observed successions of life are the only justification of a chronological arrangement of rocks. Of course, no successions of life are possible where no life exists. To pronounce a series azoic and demand the application of the palæontological dogma, is to move the previous question without debate. Whether there are or may be, good grounds other than palæontological, for a successional arrangement of terranes, is a question which will be considered in the sequel of this memoir. The mineralogical and lithological bases of various proposed divisions of the Azoic are examined, and besides their exclusion at the threshold by the canon laid down, are represented as inherently conflicting and invalid. Finally, to illustrate the misleading character of mineralogical criteria, they push the principle *in absurdum* by proposing ironically, a division of the Azoic into twelve systems based on predominant mineral characteristics.

This memoir, though characterized by a spirit of dogmatism and wholesale contempt of contemporary research, justified only by the assumption of infallibility in the work of its authors, is still, a masterly review and a forceful argument, challenging serious reconsideration of the evidences on which many of our recent judgments have been based.

T. STERRY HUNT.

Dr. Hunt's writings on pre-Silurian rocks have been voluminous and long continued. His utterances are largely of an inferential and deductive character, based on the field-observations and judgments of others, backed, however, by numerous personal reconnoissances. He appears to have been to some extent, the expositor and commentator and public representative of the Canadian survey. The value of his work in the aggregate — especially his chemical and mineralogical work, is great. He has made a durable impression on the science of his day. But his proper geological utterances, while always learned and sagacious, have sometimes possessed doubtful value. From lack of close adherence to observations made by himself, and from too much readiness to give utterance to the intuitions of the moment, he has fallen into occasional self-inconsistencies, and many conflicts with his fellow workers in geology. Partly for such reasons, I shall not follow out in detail the varying utterances which during a long life, he has placed on record.

1855. Dr. Hunt appears to have been the first to employ the term "Huronian" in its application to a series of rocks. In "A Sketch of the Geology of Canada," speaking of the rocks on the north shore of lake Huron, then recently studied by Mr. Murray, he says:

"As these rocks underlie those of the Silurian system, and have not as yet, afforded any fossils, they may probably be referred to the Cambrian system (Lower Cambrian of Sedgwick). . . This *Huronian formation* is known for a distance of about 150 leagues upon lakes Huron and Superior."*

1858. Dr. Hunt suggested evidences of the contemporary existence of organic life in the limestones, graphite and iron ores of the Laurentian.†

On the discovery of *Eozoön* so called, he discussed the mineral-

---

* *Canada at the Universal Exposition* of 1855. pp. 427, 428. [*Esquisse géologique*, pp. 28, 33. 1855]. Mr. Murray, as we have seen, had already employed the term *Huronian series*, in his report for 1855; but that was not printed till 1857. Neither he nor Hunt employed the term deliberately, as the designation of a well comprehended system of rocks, but only to express the geographical position of certain rocks referred to. In 1857, Sir William Logan made formal announcement to the American Association, that the term *Huronian* had been adopted. See *anté*, pp. 123, 124.

†*Quar. Jour. Geol. Soc.*, xv, 493.

-ogical relations of the object, and gave the name *loganite* to a supposed new mineral form.[*]

In the *Esquisse géologique du Canada,*[†] Dr. Hunt described the Laurentian system as embracing two distinct series, one resting *discordantly* on the other. These he denominated Lower Laurentian and Upper Laurentian or Labradorian (afterward called by him Norian).

The so-called "Hastings series" was first brought into notice in 1852-3 by Mr. Murray (pp. 103-108), and in the discussion of these rocks, Dr. Hunt frequently participated. In *1863*, he gave analyses of the limestones (*Rep.*, 1863, pp, 592-3). In *1867*, he stated that the Hastings series reposed in *concordant stratification* on the Laurentian gneiss, but that the Upper Laurentian or Labradorian, rested *unconformably*, not only on the Lower Laurentian, but also on the Hastings series.[‡]

In *1869*, he identified as Laurentian,[§] "the great gneissic and hornblendic formation stretching through" the northeastern portion of Massachusetts, and inclosing crystalline limestones, and on the ground of their age, promoted successfully the search for *Eozoön canadense.*

In *1870*, his attention was again turned to the geology of eastern New England,[||] and he recorded the conclusion that, "In fact, the schists and gneisses of the White Mountains are clearly distinct, lithologically, from the Laurentian and the Huronian, as well as from the crystalline rocks of the Green Mountains, and from the fossiliferous Upper Silurian strata, which lie at the southwestern base of the Canadian prolongation of the latter." (p. 84.). Turning then, to the lithological characters of the "Hastings series" in Canada, he says Mr. Vennor has shown that "it rests unconformably upon the old Laurentian gneiss, while it is at the same time overlaid by the horizontal limestones of the Trenton group. This intermediate series which attains a thickness of several thousand feet, is terminated by calcareo-micaceous schists, in which *Eozoön canadense* has been found, both in Madoc and Tudor." (p. 85.) He then summarizes Mr. Murray's observations in Newfoundland in 1866 and recognizes there a mass of rocks "immediately succeeding the Laurentian," and concludes:

"From these investigations of Mr. Murray, we learn that between the Laurentian and the Quebec group, there exists a series of several thousand feet of strata, including soft, bluish-gray mica slates and micaceous limestones belonging to the Potsdam group; besides a great mass of whitish granitoid mica slates whose relation to the Potsdam is still uncertain. To the whole of these we may perhaps give the provisional name of the *Terranovan series*, in allusion to the name of Newfoundland." (p. 87.)

---

[*] *Geology of Canada*, 1863, p. 490.

[†] *Paris Exhibition of 1867*, p 10.

[‡] *Esquisse géologique* pp. 5, 6.

[§] On Laurentian rocks in eastern Massachusetts, *Am. Jour. Sci.*, II xlix, 75-78.

[||] "On the Geology of Eastern New England," *Amer. Jour. Sci.* II. l. 83-90.

The Terranovan series therefore occupies a portion of the interval in which lies also the "Norian" and the "Huronian," and it overlaps the Potsdam. To this he referred the White Mountain rocks, as well as certain rocks in New Brunswick.

In *1868*, he prepared a memoir on the mineralogy of the "Laurentian limestones of North America[*]" in which he wrote:

"In the county of Hastings, in the Province of Ontario, not less than 21,000 feet of strata, consisting of crystalline schists, limestone and diorite are found resting *conformably* upon Laurentian gneiss." (p. 48.)

In a postscript (p. 98,) he states:

"More recent researches by the Geological Survey of Canada have shown that the rocks of Hastings county, Ontario, noticed on page 48, rest *unconformably* upon the Laurentian, and belong to one, and possibly two, distinct systems. The upper and larger portion consists in great part, of mica schist and micaceous limestones, while at the base are great masses of dioritic and hornblendic schists, with iron ore, posssibly of Huronian age."

In *1873*, he was reported as follows:

"As regards the *Norian*, which had been once joined to the Laurentian, he had elsewhere shown that we had reason for suspecting that it might be more recent than the Huronian, and possibly than the *Montalban*, a conclusion which appeared to be confirmed by the facts made known by Hitchcock."[†]

In *1875*, he returned to a study of the White mountains, or Montalban series, which he had already identified with the Hastings series. He said:

"These ancient rocks are also largely represented in Hastings county, Ontario, where they occupy a position between the Laurentian [i. e. Lower Laurentian] and the fossiliferous limestones of the Trenton group, and are the equivalents of similar limestones and micaceous quartzytes in Berkshire county."[‡]

In *1878*, Dr. Hunt referred the limestones of the Hastings series to the lower Taconic (Taconian).[*] In his "Chemical and Geological Essays," the Hastings limestones and slates are said to lie between the Huronian and Trenton.

---

[*] *Twenty-first Annual Report of the Regents of the University of the State of New York*, Appendix, pp. 47-98.

[†] *Proc. Bost. Soc. Nat. Hist.*, 1873, xv, 310.

[‡] *Proc. Soc, Bost. Nat. Hist.*, 1875, xvii, 509.

In *1878*, he prepared a synopsis [†] of his views on the classification of Eozoic (Archæan, Azoic) rocks. Their divisions were distributed as follows:

1*d*. MONTALBAN. Named in 1872[=Terranovan], well displayed in the White Mountains, and occupying large areas in New England and southwestward; a great mass of crystalline schists. Gneisses distinguished from those of the Laurentian by being finer grained and having white feldspar. They are less firm and more tender, often containing silvery mica, and pass into coarser mica schists. This series contains granular olivine rocks [*dunite*] often accompanied by enstatite [*saxonite* of Wadsworth].

1*c*. HURONIAN. Named in 1855, more or less schistose, crystalline rocks, resting unconformably on the Laurentian. "The Green mountain series." Contain jaspery petrosilex, becoming porphyritic by the presence of feldspar and of quartz in a compact base, sometimes schistose and finely laminated. Contain basally, chloritic schists altered from diabases. [The description applies to the lake Superior pseudo-Huronian, not to the original lake Huron Huronian.]

1*b*. NORIAN. The upper portion of the Laurentian series on the Ottawa river. A distinct terrane, resting unconformably upon the gneisses and crystalline limestones of the Laurentian. The former Upper Laurentian or Labradorian. Consists chiefly of anorthic [triclinic] feldspar, sometimes almost without admixture; sometimes accompanied by small portions of hornblende, of pyroxene or of hypersthene (hypersthenite or hyperite). Fine or coarse. Colors white, pale bluish or greenish, dark lavender, smoke-blue or nearly black. Titaniferous iron occurs in great beds.

1*a*. LAURENTIAN. Named in 1854, prevailingly a strong, massive gneiss, reddish or grayish, sparingly micaceous, very often hornblendic. The crystalline schists absent. Crystalline limestones present, often associated with beds of quartz. Masses of magnetite. Beneath these (the *Grenville series*) a great mass of granitoid gneiss without limestone (the *Ottawa gneiss*).

Above the Montalban is placed the TACONIAN (=Lower Taconic); QUEBEC group (=Upper Taconic or Cambrian), (pp. 10, 11, 12, 13, 21).

---

[*] *Proc. Bost. Soc. Nat. Hist.*, 1878, xix, 278; preface to second edition of *Chem. and Geol. Essays*, pp. xxii, xxvi.

[†] *The Geologists' Traveling Handbook*. By Dr. James Macfarlane, New York, 1879. It was circulated before the close of 1878.

The following is Dr Hunt's view of the taxonomy of the lower rocks in his Pennsylvania Report:*

8. SILURO-CAMBRIAN. Upper Cambrian of Sedgwick. Part of Lower Silurian of Murchison, and the Matinal of Rogers, in part.

7. CAMBRIAN. The Lower and Middle Cambrian of Sedgwick, and the Lower and Upper Cambrian of Hicks; being the Upper Taconic of Emmons, and the Quebec group of Logan: or the Primordial Silurian, and part of the Lower Silurian of Murchison. [Upper Copper-bearing rocks of Logan.]

6. KEWEENIAN. The Copper-bearing series of Lake Superior, found in the same geological interval as the Taconian, but not identified with it.

5. TACONIAN. The Lower Taconic of Emmons, or the "Hastings series," including a part of the Primal, Auroral and Matinal divisions of Rogers; and constituting with the Montalban, what he had once called Terranovan.

4. MONTALBAN. The White Mountain or Mica schist series. [Terranovan in part.]

3. HURONIAN. The Green Mountain series, or altered Quebec group of Logan. [Lower Copper-bearing rocks of Logan.]

2. NORIAN. The Labradorian or Upper Laurentian of Logan.

1. LAURENTIAN.
    - b. *Grenville series.* With limestones. Supposed unconformable with the next.
    - a. *Ottawa gneiss.* Without limestones. (pp. 215-242.)

In *1879*, the Norian was said by Dr. Hunt to rest *unconformably* upon the gneisses and crystalline limestones of the Laurentian, and held to be older than the Huronian. The Huronian was also said to rest *unconformably* on the Laurentian on the north shores of lakes Huron and Superior.

In *1886*,† Dr. Hunt's conception of the succession of the Azoic Rocks was freshly set forth with a result of which a brief abstract is as follows:

SILURIAN.
ORDOVICIAN.
CAMBRIAN.
KEWEENIAN. Upper division of Upper Copper-bearing series.

***Special Report on the Trap Dykes and Azoic Rocks of southeastern Pennsylvania.* By T. Sterry Hunt. Part I. Historical Introduction. Harrisburg, 1878 pp. 253. [Being E of the series of Survey Reports. This Report is dated 1875, though the Preface bears date 1878.]

†*Mineral Physiology and Physiography*, a second series of Chemical and Geological Essays, with a General Introduction. Boston, 1886, 8vo, pp. xvii plus 710.

Taconian. Lower division of Upper Copper-bearing series. Quebec group of Logan.

Montalban.

Huronian. ?*Pebidian* of Hicks.

Arvonian. (Formerly part of Huronian.) Petrosilex series,—jaspers and porphyry. *Hälleflinta,* Sweden. *Arvonian* of Hicks.

Norian. (Formerly Upper Laurentian or Labradorian.)

Laurentian. (Former Lower Laurentian.) ?*Lewisian* of Murch.

Grenville series. Typical Laurentian (Former Middle Laurentian.) *Dimetian* of Hicks.

*Ottawa gneiss.**

Dr. Hunt has always been resolutely opposed to the identification of the Animike Series with the proper Huronian. The following passage, among many others is explicit:

"The fact that the Taconian or Animike series in Northern Michigan, rests sometimes upon the Granitoid or Gneissic group, sometimes upon the Dioritic group, of Rominger, and elsewhere upon a mica schist series having the characters of the Montalban, goes far to show its stratigraphical distinctness from all three of these. Its separation from the Dioritic group was early noticed by Logan, when he described the unconformable superposition of this series (the lower division of his Upper Copper-bearing series) on the ancient greenstone (Huronian) series, and the presence of portions of this in the basal conglomerates of the latter. There are, however, as I have elsewhere noticed (*Azoic Rocks*, p. 202,) certain mineralogical resemblances between the Taconian and the softer and more schistose beds of the Huronian, with which they were confounded by Murray at more than one locality along the north shore of Lake Superior. Hence, after visiting the Marquette district in 1861. he did not hesitate to call the iron-bearing series of that region Huronian; a designation adopted by the Geological Survey of Canada. In this he was followed by J. P. Kimball in his study of the Marquette iron ores in 1865, by Hermann Credner in 1869, by T. B Brooks in 1873 and again by Irving in 1883. All of these include the two series under the common name of Huronian, and the estimates of the thickness of the Huronian have been based upon that of the two united. The distinctness of the underlying Dioritic group with its serpentines and chloritic rocks, which together constitute the Huronian or *pietre verdi*—alike from the older granitoid and gneissic group, from the mica-schist or Montalban group and from the great overlying Animike or Taconian system, including the quartzites, marbles, iron-ores and argillites, is however, manifest. The succession is thus brought into complete accordance with that which is found in many parts of the Appalachians, as well as in southern Europe, as is pointed out in part iv of Essay X."[*]

---

*The following references may be made to opinions of Dr. Hunt on the geology of New Brunswick: Hunt: *Geology of Canada*, 1866, pp. 235, 236; *Amer. Jour. Sci.*, II, 1870, l, p 89 (Compare *Proc. Amer. Assoc.*, 1871, p. 33;) *Azoic rocks*, 1878, 181, 188, 189; *Proc. Amer Assoc.*, 1873, B, 116, 117; 1879, 285-7; *Amer. Jour. Sci.*, 1880, III., xix, 273-5; *Boston Proc.*, 1875 xvii, 509; *id.*, xix, 278; Preface, 2d. ed. *Chemical and Geological Essays*, p. xxix; *Mineral. Physiology and Physiography*, pp. 407-8, 572-4.

Dr. Hunt, in other passages, recognizes the presence of the Animike (Taconian) or true Huronian in the Upper Peninsula of Michigan. He writes:

"Resting in some cases upon this group[†] and in others upon the granitoid rocks is a great system divided in ascending order by Rominger, in 1880, into a Quartzite group (which includes a marble series,) an Iron-ore group, and an Arenaceous-slate group, all of which appear closely connected. The system comprises heavy beds of quartzite, often schistose and with conglomerates, interstratified and overlaid by argillites of various colors, with graphitic, hydro-micaceous or sericitic slates, beds of jasper, of hæmatite and magnetite, either pure or disseminated, and, in the upper portion, limonite and siderite. The limestones form in the upper part of the quartzite division, great masses of white crystalline marble, sometimes with mica and tremolite and sahlite; at other times they are reddish or dull and compact. The iron ores appear to be in two horizons, one below and one above a great body of limestone. To the latter are referred the ores of the Gogebic and Menominee districts, and to the former, those of Marquette and Felch mountain, with which those of Vermilion lake in Minnesota, appear to be identical. The argillites which overlie the latter are those seen in the St. Louis river and at Thompson, Minnesota, which are by Rominger compared with argillites at L'Anse and Huron bay."[‡]

George F. Matthew and Associates in New Brunswick.

Several different Canadian geologists have participated in the investigation of the geology of the maritime provinces of British North America. The pioneer among them was the present Sir William Dawson, whose special studies for the greater part, have

---

[*] *Mineral Physiology*, 581-2.

[†] The Dioritic group of Rominger.

[‡] *Mineral Physiology*, pp. 579-80. The writer has elsewhere recorded his independent recognition of the existence of two discordant systems in the Marquette Iron region—*Sixteenth Annu. Rep. Minn.*, pp. 178-9, 185.

Brunswick.

-78.	Bailey, 1880.	Bailey, Matthew & Ells, 1878-9.
	Certain feldspar porphyries.	Silurian. Cambro-Silurian. Cambrian or Primordial.
llal	Upper Kingston gr.	
and stal old-	Lower Kingston. Coastal gr. Talc schists, congl. limestone. Coldbrook gr. Felistic,*14* etc.	Kingston Division: *16*. Felsite, schist, slate cong., felsite cong. and clay slate. Coastal Division: Chloritic, felspathic and talcose; schistose cong. Coldbrook Division: Petrosilex and felsite, agglomerates, diorites, etc.
olo- and	Finer gneiss, quartzites = ?Hastings. Coarse gneiss.*15*	Syenite and gneiss, quartzite, felsite, limestone, mica and felsite schists. Syenite-gneiss and felsite.

---

out, from its lithological characters placed in the Huronian.]
Coastal overlies them.
Silurian in Rep. of 1874-5, pp. 84-9.
p.

evidence of at least a partial unconformability."
blocks, or what appear to have been detached masses of gneiss
led in, the granite in such a way as to look like a coarse con-

e of Lake Superior.

been palæontological.[*] Among those who have contributed important original observations and have studied especially the oldest rocks, are George F. Matthew, L. W. Bailey and R. W. Ells. This portion of the continent presents great geological difficulties, and the interpretations of the phenomena have been very diverse. The differences, however, have been rather of local than of geognostic significance; and it is therefore not intended to trace the historical development of opinion into detail. Following Sir William Dawson, Mr. George F. Matthew, in 1863, presented the results of a well elaborated series of observations on the geology of St. John county, New Brunswick[†] and proposed an arrangement of the rocks which will be reproduced synoptically in the following table.[‡]

The table which follows is compiled from papers cited in this connection.

CHARLES H. HITCHCOCK.

Professor C. H. Hitchcock's survey in the state of Maine did not lead him into researches possessing any important bearing on the development of American opinion respecting the nature and origin of the older rocks. The official character of his connection with the Vermont survey, the first volume of the final report of which was published in 1861, though prepared in 1859, was as chemist of the survey. But, provision for the chemical work being inadequate, professor Hitchcock devoted much attention to geological investigations. Among these was the preparation of a chapter on "Azoic Rocks" and contributions on "Steatite and Serpentine" and "Saccharoid Azoic Limestone."[§]

---

[*] *Acadian Geology. The Geological Structure, Organic Remains and Mineral Resources of Nova Scotia, New Brunswick and Prince Edward's Island.* First edition, 1855, 2d, 1868 (with information posted to date), 3d, 1878. For other recorded opinions of Sir William Dawson, see *Can. Nat. and Geol.*, 1861, I, vi, 164; *Quar. Jour. Geol. Soc.*, 1862, xviii, 303. Sir W. E. Logan made a reconnoissance of the Bonaventure formation in 1843; and Dr. Abraham Gesner made a report to the New Brunswick government at nearly the same date.

[†] *Canadian Naturalist and Geologist*, viii, 241-260, Aug. 1863. For later views see *Quar. Jour. Geol. Soc.*, 1865, xxi, 422-434.

[‡] The later studies of Messrs. Matthew, Bailey, Hartt, Ells and others may be consulted as follows: Bailey: *Canadian Naturalist*, 1864, 81-97 (a rapid reconnoissance); Bailey, Matthew and Hartt: *Observations on the Geology of Southern New Brunswick*, 1865: H. Y. Hind: *Prelim. Report on the Geol. of New Brunswick*, 1865; Bailey and Matthew: *Proc. Amer. Assoc.*, 1864, xviii, 179-195 (revised to April, 1870); Bailey and Matthew: *Geol. of Can. Report of Progress*, 1870-71, 13-240 (proposing numerous changes on recommendation of Dr. Hunt); Matthew: *Report*, 1874-5, pp. 84-9; *Report* for 1876-7, 322-350; Hugh Fletcher: *Same Report*, 405-426; R. W. Ells: *Rep. Prog.* for 1877-8, D., pp. 1-12; L. W. Bailey: *Rep.* 1877-8, DD., pp. 1-34; G. F. Matthew: *Same Rep.*, E, pp. 1-6; Bailey, Matthew and Ells: *Rep.*, 1878-9, D., pp. 1-26; R. W. Ells: *Rep.*, 1879-80, D., pp. 30-42; *Rep.*, 1880-82, D., pp. 17-19: Bailey: *Proc. Amer. Assoc.*, 1880, 416, 417: *Can. Rep.*, 1882-4, E., pp. 31-34; A. P. Low: *Rep.*, 1882-4, F., pp. 16-20; R. W. Ells: *Rep.*, 1885, E. pp. 54-63. Dr. T. S. Hunt's recorded opinions have been already referred to, *Ante.* p. 150

[§] *Geology of Vermont*, I, pp. 452-474 and 533-558.

In consonance with views generally prevailing at the time, he expresses the opinion respecting the azoic rocks, that "stratification and lamination appear to have been produced by original deposition in water." Speaking of the difficulty of distinguishing, in some cases, between the lines of sedimentary structure and cleavage and foliation, he says: "We have not attempted it [distinction of cleavage] to much extent in the slates of Vermont; still less have we tried to draw a line of distinction between the foliation of the schists and stratification; for this is a still more difficult work. Hence the strikes and dips which we shall give are those of foliation and cleavage. But we believe that these usually correspond essentially with the stratification. In the fossiliferous clay-slates of the western part of the State, as well as in the limestones, we not unfrequently have found the cleavage planes making quite an angle with those of the original deposition; but in all those belts of slate interstratified with the more thoroughly metamorphosed schists, the two seem usually coincident." (p. 452.)

No attempt is made to give the azoic rocks either a systemic, a geognostic or a chronological arrangement. Fifteen species are enumerated and lithologically described. Five and a half quarto pages are devoted to a catalogue of isolated instances of strike and dip, though very little attempt is made to correlate them in a general system of structure. It is stated however, that three distinguishable ranges of gneiss traverse the state: the Green mountain range, the middle range and the Connecticut river range. The first of these is thought a continuation of the Hoosac mountain range—the gneiss of the Green mountains resulting from the accession of feldspar to the mica schist of Massachusetts, though often, in Vermont, passing again into mica schist. Of some of the gneiss of the range along the Winooski, he says "it resembles sandstone—the crystals of feldspar being rounded like large grains of sand. (p. 465.) The middle range is less extensive and more distinctly gneissic. Eastward it graduates into mica schist. The gneissic range near the Connecticut river consists only of three patches."

The unessential character of the recognized distinction between gneiss and mica schist, as indicated in the transitions along the strike, mentioned above, is emphasized by further statements. "Those layers of the rocks" he says, "on both sides of the mountain, which all would regard as gneiss, are generally interstratified with other layers of mica or talcose schist and quartz; and the judgment of good observers would differ about the line where the gneiss predominates over the schists." "Also, as we pass northerly along the line of strike [of the Green mountain range] along the eastern margin, the gneiss is rapidly succeeded by mica and talcose schists..** We incline to the opinion, however, that a narrow belt of Green mountain gneiss does extend across the whole State of Vermont.** We have expressed the opinion in another place, that gneiss, mica and talcose schist, and even some beds of quartz, may be only metamorphic varieties of the same original formation." (p. 470.)

Of hornblende rock he says: "It is found associated with gneiss and clay-slate in positions much like dikes, as well as in regular beds." Referring to the opinion expressed by MacCulloch, that hornblende rock and hornblende schist may result from the metamorphism of clay-slate, professor Hitchcock states that Bischof has shown it possible that "even in lava, the hornblende [sometimes present] was not formed at the time of the protrusion of the lava, but subsequently in the wet way; and the associations of hornblende schist forbid the idea that it was a volcanic product."

In reference to steatite and serpentine, professor Hitchcock states that "there are at least sixty beds of steatite in Vermont, and twenty-five beds of serpentine. The aggregate of serpentine is more than double that of steatite. Regarding the steatite and serpentine rocks as of one age in each range, he concludes that there are four ranges, and that these are of different ages.

As to origin, he regards serpentine as originally stratified, referring to its conformability with the foliation of the rocks which embrace it. There is no protruded serpentine in Vermont. Steatite, probably, had a similar origin. He believes in the change of "some beds of hornblende schist and diorite or greenstone, into serpentine." (p. 554.)

In general connection with the subject of metamorphism, professor Hitchcock makes the following just remarks:

"The distinction between stratified and unstratified rocks has been usually regarded as one of the most trenchant and reliable in the science of geology. And so long as it was considered a certain fact that the stratified rocks were exclusively deposited by water, and the unstratified all resulted by dry heat, it is not strange that geologists should have looked upon the line between the two classes as very distinct and recognizable. But now that it is so generally admitted that hot water has been the most efficient agent in metamorphosing the stratified rocks, and converting some of them into the unstratified, we can see how the distinction between them should often be very obscure and uncertain. Such is certainly the case with serpentine and dolomite, both of which are sometimes stratified and sometimes unstratified. We are apprehensive that some other system of classification must be adopted, to include such rock and also such varieties of gneiss, and even some of the schists." (pp. 554-5.)

The results of the studies of professor Hitchcock and his collaborators in the geology of New Hampshire are embraced in three massive royal octavo volumes.* They embody a vast amount of faithfully elaborated information in a region of extreme difficulty, which had hitherto received vastly less geological than mineralogical study. The state presented extraordinary difficulties, arising, *first*, from the absence of organic remains, those time-marks by which the geologist is able to recognize his position in the progress of æons past, and *secondly*, from the destruction of the traces of superposition by those orogenic disturbances which almost wholly obliterated the records originally made; and *finally*, by the metamorphism which had not only transformed the aspects and constitution of rock-masses, but had effected alterations of such varying nature and degree as to defy identification by the usual resemblances. In this trackless geological wilderness the geologist entered, meagrely equipped for his great work, and reported to the state and to the world the progress made from year to year, until lapse of time and exhaustion of means rendered it imperative to pronounce final verdicts. As a matter of obvious necessity, the geological conception underwent revision and augmentation with every season's addition of knowledge. But it was a peculiar merit of professor Hitchcock's advancing work that he was ever ready to announce the shape which his conception of the State's geological structure and history had attained after the latest acquisitions of observed fact. A less unsuspicious mind—perhaps it might be said, a more judicious method, would have enforced more reserve. The difference would be that a more prudent investigator would have reached thoughts not more mature and final, but would have held his "best thoughts" in reserve; while Hitchcock freely shared them with the public. It has been found possible to cast censure on professor Hitchcock that his annual announcements of status reached were so conflicting and changeful; but a just and generous view must regard them simply as marks of the progress of ideas, and encouragments to all who may be grappling with equal difficulties.

***Geology of New Hampshire.* By C. H. Hitchcock, J. H. Huntington, Warren Upham and G. W. Hawes, Volume i, containing Part I, (1874) "Physical Geography." 668pp; Volume ii, (1877,) containing Part II, "Stratigraphical Geology." 685pp; Volume iii, (1878), containing Part III, "Surface Geology," Part IV, "Mineralogy and Lithology," Part V. "Economic Geology."

It occurs to the writer that it may be best to present first, the series of provisional conclusions announced by professor Hitchcock in the progress of his work. These are taken substantially as compiled by Whitney and Wadsworth—the order of arrangement being inverted, in conformity with the method of this memoir.*

ANNUAL REPORTS. 1860-1872.

First Annual Report, 1869.

- Upper Schists.
- Quebec Group.
  - Auriferous Conglomerate.
  - Clay Slate.
  - Copper Belt.
  - Lower (mostly green) Schists.
  - Staurolite Schists.
- White Mountain series (Gneissic, Granitic)

2d Annual Report, 1870.

- Clay Slates.
- Calciferous Mica Schist.
- Coös Group.
- Lower Silurian.
  - Quebec Group.
  - Merrimac Group.
- Common Granite.
- Porphyritic Granite.
- Laurentian (?) Exeter Syenites.
- Eozoic (White Mountain or Gneissic Series).
  - Soapstones.
  - Limestones.
  - Quartzyte.
  - Porphyritic Granite.
  - Syenite.
  - Granite.
  - Chiastolite Slates.
  - Andalusite Gneiss.
  - Feldspathic Mica Schist.
  - Granitic Gneiss.
  - Ferruginous Gneiss.
  - Normal Gneiss.

3d Annual Report 1871.

- Coös Group.
- Clay Slate and Quartzytes.
- Laurentian (?).
  - Norian.
  - Brecciated Granite.
  - Trachytic Granite.
  - Common Granite.
  - Andalusite Gneiss (White Mountain Gneiss),
  - Gneiss.
  - Bethlehem Gneiss.
  - Porphyritic Gneiss.

4th Annual Report, 1872.

Division 3.

- Andalusite Slates of the Coös Group.
- Mica Schist.
- Quartzyte.
- White Mountain Series.
  - Andalusite Gneiss, Ordinary and Imperfect Gneiss, the Concord and Fitzwilliam Granite, Soapstone and Limestone.
- Granite Gneiss.
- Laurentian.
  - Granite and Porphyritic Gneiss.

Division 2.

- Norian (Pemigewasset Basin).
  - Green Granite and Syenite.
  - Four Series of Compact Feldspar.
  - Spotted Granite.
  - Common Granite.
- Laurentian.
  - Franconia Breccia.
  - White Mountain or Andalusite Gneiss.
  - Bethlehem and Berlin Gneiss.
  - Porphyritic Gneiss and Granite.

Division 1.

- Helderberg.
- Cambrian.
  - Coös Group.
    - Decomposing Slates, Dikes.
    - Calciferous Mica Schist.
    - Mica and Argillaceous Schists.
    - Quartzytes, Staurolite Schists.
  - Auriferous Clay Slates.
- Huronian.
  - Conglomerates and Quartzytes.
  - Hydromica and Talcose Schist.

PROC. AMER. ASSOC. ADV. OF SCI., 1872. xxi, 134, 135, 150.

- II. Palæozoic.
  - Clay Slates.
  - Helderberg Limestones,
- I. Eozoic.
  - 5. Older Cambrian.
    - Merrimac Group and probably Calciferous Mica Schist of the Vermont survey.
    - Coös Group.
  - 4. Huronian.
    - The Talcose Schist Series.
  - 3. Exeter Syenites.
  - 2. Norian.
    - *f.* Red compact and Crystalline Orthoclase Felsite.
    - *e.* Dark compact Orthoclase Felsite.

**Bull. Mus. Comp. Zool.*, Vol. vii., p. 306.

d. Compact Labradorite Felsite.
c. Ossipyte.
b. Trachytic Granite.
a. Common Granite.
1. Laurentian.
f. Range of Gneiss between Whitefield and Milan, considerably Hornblendic.
e. Gneiss on both flanks of the Porphyritic variety in the south part of the State, carrying the Concord and Fitzwilliam Granite, and is probably the Beryl-bearing Series.
d. Gneiss of Lake Winnipiseogee Basin.
c. Bethlehem or Talcose Gneiss.
b. White Mountain Series or Andalusite Gneiss.
a. Porphyritic Gneiss.

PROC. BOSTON SOC. NAT. HIST., 1873.
xv, 304-309.

V. Palæozoic.
B. Clay Slates.
A. Helderberg Limestone.
IV. Mostly Cambrian (?).
F. Mount Mote Conglomerates.
E. Green Granite.
D. Clay Slates.
C. Coös Group.
B. Merrimac Group.
A. Mica Schists of Rockingham County.
III. Huronian.
Feldspar and Talc.
Whitish Schists.
Green Schists.
Talcose and Auriferous Conglomerates.
II. Laurentian.
H. Syenites of Exeter and Tripyramid.
G. Reddish compact Orthoclase.
F. Red compact Orthoclase.
E. Dark compact Orthoclase.
D. Dark compact Labradorite.
C. Ossipyte.
B. Spotted Granite.
A. Common Granite of the White Mountains.
I. Laurentian (?).
C. White Mountain or Andalusite Gneiss.
B. Bethlehem Gneiss.
A. Porphyritic Gneiss.

PROC. AMER. ASSOC. ADV. SCI., 1873.
xxii, 120-131.

Winnipiseogee Lake.

Eozoic.
Mica Schist.
Eruptive Syenite.
Labradorian.
Felsites or Compact Feldspars.
Eruptive Granites of the Ossipee Mountains.
Laurentian (?).
White Mountain Series.
Winnipiseogee Lake Gneiss Formation.
Porphyritic Gneiss or Granite.

GEOLOGY OF NEW HAMPSHIRE, 1874
i, 506-539.

Helderberg Period.
Mica Schist Period.
Coös Group.
Cambrian Auriferous Clay Slates.
Merrimac Group.
Rockingham Mica Schist.
Eozoic.
Huronian.
Conglomerate.
Serpentine with Silicious Schist, and Dolomite and Soapstone.
Copper and Iron Beds.
Labrador.
Eruptive Syenite.
Fine Sedimentary Deposits.
Chocorua Granite.
Albany Granite.
Conway Granite.
Atlantic.
Franconia Breccia Group.
Montalban.
Lake Gneiss.
Bethlehem.
Laurentian.
Porphyritic Gneiss.

WALLING'S ATLAS OF NEW HAMPSHIRE,
1877.

Palæozoic.
Silurian.
Slates, Conglomerates, etc.
Helderberg Limestones.
Cambrian.
Mt. Mote Conglomerate.
Clay Slates.
Coös Group.
Calciferous Mica Schists.
Rockingham Schists.
Huronian.
Auriferous Conglomerate.
Lyman Group.
Lisbon Group.
Labrador or Pemigewasset.
Exeter Syenites.
Compact Feldspar.
Ossipyte.
Chocorua Granite.
Albany Granite.
Conway Granite.
Atlantic.
Franconia Breccia.
Montalban or White Mountain Series.
Lake Winnipiseogee Gneiss.

- Bethlehem Gneiss.

Laurentian.
- Porphyritic Gneiss.

GEOLOGY OF NEW HAMPSHIRE, 1877.
ii, 674, 675.

I. Stratified Groups.

- Palæozoic.
  - Lower Helderberg.
  - Calciferous Mica Schist.
  - Coös Group.
    - Staurolite Slate.
    - Mica Schist.
    - Quartzyte.
  - Cambrian Slates.
- Palæozoic (?).
  - Kearsarge Andalusite Group.
  - Rockingham Mica Schist.
  - Merrimac Group.
  - Ferruginous Slates.
- Eozoic.
  - Upper Huronian.
    - Auriferous Conglomerate.
    - Lyman Group.
    - Lisbon Group.
    - Swift Water Series.
    - Hornblende Schist.
  - Lower Huronian.
  - Labrador.
  - Montalban.
    - Franconia Breccia.
    - Fibrolite Schists.
    - Ferruginous Schists.
    - Concord Granite.
    - Gneiss and Feldspathic Mica Schists.
- Laurentian.
  - Lake Winnipiseogee Gneiss.
  - Bethlehem Fine-grained Gneiss.
  - Bethlehem Ordinary Gneiss.
  - Porphyritic Gneiss.

II. Eruptive Masses.

- Augitic.
  - Diabase.
  - Diorite.
- Feldspathic.
  - Trachyte.
  - Pequawket Breccia.
  - Porphyry.
  - Labradorite Diorite.
- Granitic.
  - Exeter Syenite and Diorite.
  - Syenite of Mt. Gunstock, &c.
  - Granite not otherwise Assigned.
  - Granite cutting Coös Group.
  - Chocorua Series.
  - Albany Granite.
  - Conway Granite.

In a region where palæontological aids to investigation are wanting, the geologist must rely on indications of superposition, physical conformities, characteristic minerals and petrographic resemblances. The application of the petrographic criterion is involved in distracting difficulties by the progressive and unequally-paced changes which crystalline aggregations have undergone in the presence of the dynamic agents of geology. Hence the greater necessity for seeking always the evidences from superposition. Professor Hitchcock, with a true evaluation of the only expedients available, enunciated in 1873, the fundamental principles by which he was guided:

"Logan, in 1855," he says, "described a system of rocks overlying unconformably the Laurentian gneisses about Lake Huron, which were distinguished by means of lithological characters. All geologists, therefore, who use the name Huronian, of necessity practically adopt this principle, though perhaps insensibly. We do not claim that a talcose rock can never be found in any other system than the Huronian, nor that gneiss may never be stratified with the hydromicas. Professor Dana's recent paper shows that gneisses, quartzites and limestones are interstratified in the Silurian of western New England.* In no instance would we claim that mineral character is sufficient to distinguish systems without a study of the relations of the strata. We may sometimes generalize, and believe that rocks of similar mineral characters must be of the same age, but such speculations must always provide for confirmation by a study of the strata."[*]

---

*Proc. Amer. Assoc., 1873, Sec. B, p. 147.

An application of the mineralogical criterion is seen in what, in the report for 1870, is called "porphyritic gneiss."

"There are over Thirty areas of porphyritic gneiss in which the feldspar crystals are very conspicuous for their size, the rock being the *Augen-gneiss* of Europe. I assume that all the areas of this rock are identical in age, and in speculating upon the relative positions of the intervening groups, rely upon the correctness of this starting-point.* * The fact of minor differences would seem to confirm our assumption of their identity in age, just as the palæontologist finds, from the presence of the same fossils, proof of contemporaneity in the rocks with dissimilar mineral character. From these facts it is inferred that the porphyritic gneiss is older than the Lake or the Montalban gneisses, the last being the newest.* * It may as well be said now as at any time, that nothing older than the porphyritic gneiss has yet been discovered. This formation constituted the first dry land in the State."[†]

Professor Hitchcock's changes of opinion are illustrated in his record in reference to the Norian. This division, following Hunt, was first introduced into the report for 1871. Of its relative position he says:

"All will agree that the mineral labradorite belongs to the original Laurentian system; and therefore, by its discovery in New Hampshire, will be satisfied that some of our crystalline rocks belong to the older series of the Eozoic, and not the Palæozoic. Hence the prevalent opinion respecting the age of the New England metamorphic rocks must be changed to conform with the discovery of labradorite in our state.* * Our conclusions as to the absolute and relative ages of the New Hampshire formations depend upon the reference of some of them to the Norian system of Hunt."[‡]

Professor Hitchcock, therefore, in establishing the high geological antiquity of the White mountains, had a long-strengthening sentiment to combat. It was recognized however as Norian by Hunt, in 1873.[*]

---

[*] *Pro. Amer. Assoc.*, 1873, Sec. B. p. 147.

[†] *Final Report* vol. ii, pp. 659, 660, 663, 664.

[‡] *Report, 1871*, pp. 4-10. The allusion made in the above paragraph may be illustrated by the following citations: "To the Chemung and Portage group of New York* * may perhaps be referred, in part, the rocks of the White Mountains (Hunt, *Amer. Jour. Sci.* 1850, II. ix, p. 19; *Proc. Amer. Assoc.* 1849, II, pp. 333,334.) "It is moreover probable that the rocks of New Hampshire, including the White Mountains, are altered strata of Devonian age." (Hunt, *Geol. of Canada*, 1863, p. 598.) The same opinion was reiterated in 1867 (*Esquisse géologique du Canada*, p. 23; *Bull. Soc. géologique de France*, 1867, II, xxiv. p. 687.) In 1860, professor J. P. Lesley expressed the opinion that the range of the White Mountains would prove to be synclinal instead of anticlinal, and therefore of probable Devonian age. (*Proc. Acad. Nat. Sci. Phil.*, 1860. xii, pp. 363-364.) Logan, also, accord-

In 1872, Hitchcock more formally defended the supposed sedimentary character of these rocks:

"It is a perplexing matter to determine the lines of stratification, as the outcrops are divided by two prominent sets of jointed planes, either of which might be called layers of deposition, the rock being essentially homogeneous. One set dip 20° northerly, and are the most numerous, The other dip about 75° W10°S."[†]

In the Report for 1872, published later than this, he adds:

"As the latter [joints] correspond better in position with the supposed strata of nodular gneiss, it was thought they indicated the proper lines of deposition."[‡]

These beliefs were iterated in 1872. Referring to the same locality and the same terrane, he says:

"The rock seems to be stratified, its planes dipping about 20° northerly * * The importance of this discovery may be best appreciated by remembering that the presence of the lime feldspars affords a strong presumption that the rocks are Eozoic, and not metamorphic Palæozoic formations. It seems to be generally admitted by geologists that the feldspars are confined to the older rocks, except as found in eruptive trappean and volcanic masses."[§]

In the second volume of the Final Report, he adheres to the same opinions:

"I was at first satisfied that this rock was gneiss, but did not recognize its true place in the porphyritic group. Subsequently I referred it to the "trachytic" or Albany granite, but a re-examination in 1875, shows that it belongs to the oldest of our formations, and is distinctly stratified, traversed by trap dykes, and narrow banded veins of quartz * * The labradorite rocks with a very moderate dip, rest unconformably upon the greatly upturned edges of the Montalban schists, as if there had been large upheavals at the close of the Montalban period, and comparatively little disturbance since. * * The facts as interpreted, are of great consequence, since they fix the geological horizon of the whole

---

ing to Hunt, regarded them as probably "altered Devonian strata" (*Azoic Rocks* pp. 86, 87, 182.) (See also *Amer. Jour. Sci.*, II, ix, 19, 1849; II, xxxi. 403, 1861.) In 1870, Hunt pronounced the White mountains Terranovan. *Amer. Jour. Sci.*, II. l. 83-90, 1870. The various older opinions are reviewed at length by Hitchcock in Final Report, ii, 184, 198, 264-7.

[*] *Proc. Boston Soc. Nat. Hist.* xv, p. 310, 1873.

[†] "The Norian Rocks of New Hampshire," *Amer. Jour. Sci.* III, iii, 43-47, 1872.

[‡] *Ann. Rep. 1872.*, pp. 15, 16.

[§] *Proc. Amer. Assoc., 1872.*, xxi, pp. 135-151.

Atlantic system, while considerations of a stratigraphical character confirm this impression. * * The discovery of the Labrador system, overlying the most abundant and characteristic White Mountain strata, makes it clear that the latter are older than the former, which are confessedly Eozoic."*

In spite of this oft repeated conviction of the sedimentary nature of these labradorite rocks, and of their occurrence in seven different areas among the White mountains, we find professor Hitchcock on a later page of the same volume, employing the following language:

"The Labrador system, if present in New Hampshire, is in very limited amount. Recent investigations make it difficult to say that the labradorite rocks are not of eruptive character. They have the composition of dolerite; and certain exposures of them upon Mount Washington are surely injected dykes. Hence great doubt arises whether the larger area of Waterville really represents the Labrador system of Canada. At all events, its age is great, for these dykes cut through the Montalban strata [He had very recently said the labradorite rocks rest discordantly on the upturned edges of the Montalban]. This dolerite may be regarded as one of the oldest eruptive rocks in the State, coming to the surface in what was the labrador age of the world."†

The eruptive nature of this mass was detected by Dr. Hawes; and is recorded in the third volume of the New Hampshire report, dated 1878, though it does not appear at what date Part iii was printed, nor at what earlier date it was prepared. He says:

"Gabbro is found in immense masses in Waterville and in the vicinity of Mount Washington. The relationships of its masses to the surrounding strata are not so easily determined as those of the little dikes of diabase and diorite, the walls of which are usually plainly seen; but at some points the rock possesses all the structure of an eruptive mass and when, in other places, this is not found, the evidence furnished by more favorable localities, as well as that furnished by allied rocks in other lands where they have been more thoroughly investigated, must at present be decisive."‡

Dr. Hunt now found occasion to change his position:

"The labradorite rocks in the White Mountains, which had by Hitchcock been referred to norite, are now found by him to be eruptive masses."§

The "porphyritic gneiss" always commanded the attention of

---

*[*] *Final Report* II. pp. 214,258,266.

*[*] *Final Report*, II, p. 667.

‡ *Final Report New Hampshire*. III. p. 165.

§ *Azoic Rocks*, p. 161.

professor Hitchcock. He early published observations as follows:

"The sections given of the common granite, trachytic granite and the Norian series (or at least certain felsites) seem to determine their relative positions, the last being at the top. The brecciated granites of Franconia seem to be older than any of these and to underlie them. * * If these points are assumed, the porphyritic gneiss can be shown to be at the bottom of the series, for it lies outside of the lowest of them."*

In the next annual report the "porphyritic group is described as consisting "mainly of gneiss full of large crystals of orthoclase feldspar, associated with ferruginous and other bands. It is regarded as the oldest of all the formations in the State," for reasons which are enumerated."†

The position of this gneiss is again referred to:

"If the felsite series is of the age of the Upper Laurentian or Labrador of Logan, then by the law of superposition, the strata underneath the common granite are Lower Laurentian. Observation showed us, at this phase in the development of the White Mountain structure, two gneisses and a breccia underneath the granitic sheet. The most important is the "Porphyritic gneiss," or granite sometimes. This is a gneiss having large crystals, usually one and a half inches long, of orthoclase, arranged in layers in the mass, with the longer axes parallel to each other. These we conceive to be the strata.* *

"The descriptions of the Laurentian rocks in Canada and Europe make mention of large quantities of porphyritic gneiss; hence we feel warranted in referring these lower schists to the Laurentian system. We have found nothing older in the state." ‡

Again, in a later discussion of the parallelism of the groups recognized in New Hampshire, having mentioned the Canadian systems, Laurentian, Labrador, Huronian and Cambrian, he says:

"The first two of our groups may be referred to the oldest of these, the Laurentian, without hesitation. We do not possess exhaustive information about the occurrence of this oldest system in other regions. So far as is understood, there are two sorts of associated rocks in its typical localities, one being largely pyroxenic. That variety is wanting in New Hampshire. A porphyritic or *Augen-gneiss* is eminently characteristic of the fundamental rocks in every part of the world; and hence ours may readily be called Laurentian. * * [After correlating succeeding New Hampshire

---

***Annual Report*, 1871, pp. 25-27.

†*Annual Report*, 1872, p 11.

‡*Proc. Amer. Assoc.*, 1872, xxi, pp. 145-6.

groups, he continues.] The Montalban series are certainly not characteristic of the Laurentian. * * Dr. Hunt is satisfied that they overlie the Huronian or greenstones. Our own observations lead to the view that the typical Montalban rocks underlie the same, as recently stated, though the precise relationship is not beyond controversy."[*]

I make but two citations further bearing on the structural character and taxonomic disposition of New Hampshire Archæan rocks. The first is connected with the genesis of certain systems:

"If these granites behave like a stratified formation, of course the question is at once raised whether they should not be regarded as true strata. The answer cannot be given from position merely, since it is not uncommon to find sheets of trap or lava holding a perfectly analogous position. We have preferred to think of the White Mountain country, at the end of the Laurentian period, as an immense basin, upon which there was an overflow of common granite. Being liquid it spread itself out like water, assuming a horizontal surface. After a while, there was an eruption of trachytic granite, which spread itself in the same way. Subsequently the felsites were formed above them conformably. It would be natural to regard these granites and felsites as belonging to one period, the Norian. The limits of this system have not been fixed; and it seems as if in New Hampshire, it should commence in the common granite and end with the red orthoclase felsite."[†]

The second citation is an observation of Mr. Huntington, who says of the porphyritic gneiss:

"The fact that rounded fragments of a dark gneiss are found in the porphyritic, shows that the porphyritic rock in Fitzwilliam is either intrusive, or that in the process of metamorphism, these fragments were not obliterated, and that the dark gneiss — which is very limited, but resembles some varieties of the Bethlehem gneiss — is the older rock."[‡]

Reference has been made to the evidence borne on the pages of the Vermont and New Hampshire reports, that the geological disorder reigning in those states is of the most perplexing character. Observations of strike and dip defy co-ordination, except within very limited areas. Many pages are devoted, in different portions of the second volume, to records of dip and strike, but no general tendencies to groups or systems of strikes is distinctly apparent.

[*] *Final Report*, ii, 668, 669. See further, pp. 98, 99, 102, 274.

---

[*] *Proc. Amer. Assoc.*, 1872, xxi, 145.

[*] *Final Report*, ii, 472. See also, pp. 513-514.

I copy at random, for illustration, the records made of the dip of the rocks of the "Montalban series" in a single town, Grafton:

At McKelton's, S. 60° E., 72°.
At mica quarry, N. 32° E., 80°.
At west side, S. 50° E., 75°.
At north, S. 63° E., 70°.
At ¼ mile southeast of J. Martin's, S. 78° E., 70°.
At Alger hill, N. 62° E., 75°.
At H. Bullock's, S. 38° E., 50°.
At Prescott hill, N. 82° E., 40°.
¼ mile northeast of T. Foss', S. 65° E., 70.°
At Mrs. Arvin's, S. 62° E., 78.°
At Tewkesbury pond, S. 33° E., 75.°

Nevertheless, professor Hithchcock has given us, near the close of this volume, a chart of "Principal axial Lines of Vermont and New Hampshire." He says: "This is the final summing up of all the multitudinous observations of this report. * * This map and the statements of the last few pages are the key to Part II. They are the generalizations derived from our entire work, both in the New Hampshire and Vermont surveys."*

Turning to the chart, we observe a series of broadly sinuous lines drawn across the two states, having in western Vermont a general direction nearly north and south; in the eastern part of the state, a general conformity to the trend of the Connecticut river; and in New Hampshire, a still stronger tendency to a NNE direction, with some irregularities in the White Mountain region. These are simply lines of observed structure. We are told also, that at every point, they are the average of the different strikes observed. This is worth something; but geologists will be better satisfied, when, from this multitude of discrete data, some later hand, if not professor Hitchcock's, shall have evolved the deep historic and genetic truth concerning the sequence and vicissitudes of this puzzling complex of terranes.

Thomas Benton Brooks.

1873. The progress of the investigation undertaken by Major Brooks under the auspices of the Geological Survey of Michigan, in 1869, was shaped by complete sympathy with the general views then prevailing; and those, it is just to say, were strictly Canadian. The Canadian survey had settled in the conviction that the iron-bearing rocks of the Marquette region were all of one age, and they were of the same age as the rocks north of lake Huron which they

---

Final Report. II, p. 673.

had long known as Huronian. Thus the geologists of Michigan came into the traditional belief that the whole territory of the Northern Peninsula of the state was covered by the Huronian and Laurentian systems—save the recognized Lower Silurian angle at the east—the St. Mary's peninsula. Major Brooks, as the result of four years of investigation, concluded that the whole geology of the Marquette district above the Laurentian, might be embraced in a certain number of groups, which he designated numerically. As the characterization of these groups will be the best exhibit of major Brooks' views, and as these numerical designations are necessary matters of frequent reference among geologists, they will be at once presented.*

XX. *Granites* southwest of Lake Michigamme (Taken from *Wis. Rep.*, iii. 648.
XIX. Grayish-black *Mica-Schist*, often staurolitic, and holding andalusite and garnets, Rarely *chloritic schists.*
XVIII. (Doubtful). *Quartzyte* west end of Lake Michigamme?
XVII. *Anthophyllitic schist*, with iron and manganese.
XVI. (Uncertain.) Contains some hæmatite.
XV. *Argillyte.*
XIV. *Quartzyte*, often conglomeritic. Position immediately over the ore. Contains neither marble, talc nor novaculyte; very rarely argillyte.
XIII. *Specular and magnetic ore.* The principal bed.
XII. Banded, ferruginous, *Jaspery schist.*
XI. Coarse *dioryte*, with a light grayish and reddish feldspar.
X. *Silicious, ferruginous schists.*
IX. *Dioritic rock.*
VIII. Silicious, *magnetic schists.* "Flag-ores."
VII. *Dioritic rock.*
VI. Silicious, magnetic, banded, *chloritic schists.*
V. *Quartzyte*, sometimes containing marble (used as flux) and beds of *argillyte* and *novaculyte.* Very persistent. Very seldom conglomeritic.
IV. *Silicious, ferruginious schist.*
III. *Silicious, ferruginious schist.*
II. *Silicious, ferruginous schist.*
I. *Silicious, ferruginous schist.*
[The crystalline schists follow below.]

"These beds," he says, "appear to be metamorphosed sedimentary strata, having many folds or corrugations, thereby forming in

---

*The table is compiled from the *Michigan Report*, Vol. i. pp. 85-116.

the Marquette region, an irregular trough or basin, which, commencing on the shore of Lake Superior, extends west more than forty miles * * While some of the beds present lithological characters so constant that they can be identified wherever seen; others undergo great changes. Marble passes into quartzite, which in turn, graduates into novaculite; diorites almost porphyritic, are the equivalents of soft magnesian schists. * * The total thickness of the whole series in the Marquette region, * * may aggregate 5,000 feet.

"Near the junction of the Huronian and Laurentian systems, in the Marquette region, are several varieties of gneissic rocks, composed in the main of crystalline feldspar, with glassy quartz and much chlorite. Intersecting these are beds of hornblendic schist, argillite and sometimes chloritic schist. These rocks are entirely beneath all the iron beds, seem to contain no useful minerals or ores, and are of uncertain age. No attempt is here made to describeor classify them." (p. 84.)

Of the "diorytes, dioritic schists and related rocks" he says: "These obscurely bedded rocks * * range in structure from very fine-grained or compact (almost aphanitic) to coarsely granular and crystalline, being sometimes porphyritic in character. * * On the one hand it graduates into a heavier, tougher, blacker variety, which is unquestionably hornblende-rock, with some feldspar. * * On the other hand, it passes into a softer, lighter colored rock, of lower specific gravity, which while it has the same streak, weathers similar to true diorite, is eminently schistose in character, splitting easily, and appearing more like chloritic schist than any other rock. (p.99.)

"At several points, dioritic schists, semi-amygdaloidal in character, were observed; and in one instance, the rock had a strong resemblance to a conglomerate." (p. 99.)

"At Republic mountain, a doleritic schist graduates into a black mica-schist," (p. 100). Dr. Hunt expresses the opinion that in the case of Marquette diorites the hornblendic mineral often becomes softened and hydrated, passing into a degenerate form more nearly allied to chlorite or delessite (in which water is an essential constituent) than to a true hornblende." (p. 101.)

"The bedding of the rocks is generally obscure, and in the granular varieties, entirely wanting. It is usually only after a full study of the rock in mass, and after its relations with the under- and overlying beds are fully made out, that one becomes convinced, whatever its origin, it presents in mass, precisely the same phenomena, as regards stratification, as do the accompanying schists and quartzites." (p. 102.)

Of magnesian schists, ("mostly chloritic,") he says:

"Intercalated with the pure and hard mixed ores at all the mines worked in formation XIII, are layers of a soft, schistose rock, of some shade of grayish-green, and often talcy in feeling. * * It is unquestionably a magnesian schist, varying from chloritic to talcose in character, and sometimes apparently containing a large percentage of argillite." (p. 104.)

"A very peculiar occurrence of this rock are the so-called 'slate-dykes,' which can be seen at the New England, Lake Superior and Jackson mines, but still better in the quartzite ridge just north of the outlet of Teal Lake."*

Speaking of the quartzyte (No. XIV,) he says:

"As if to leave in our minds no shadow of doubt as to the sedimentary origin of this rock, nature has, in addition to the conglomerate on the Spurr mountain range, given us a variety of the Upper Quartzite, which can only be described as a fine grained, friable banded sandstone." (p. 108.)

In discussing argillytes, he says, in addition to beds interstratified in the quartzytes:

"At least two distinct beds of argillite have been made out; one immediately beneath the ferruginous schist of formation X, to be seen in outcrop on the south shore of Teal Lake, near west end, and in the rail-road cut about one mile east of Negaunee. Another and far more extensive bed is XV, which forms the stratum next above the upper quartzite. Color usually dark brown or blackish; but where associated with the marble, it is sometimes reddish. It has a true slaty cleavage distinct from the bedding. * * Black, carbonaceous matter is often present." (p. 111.)

"Beyond the limits of the Marquette region, we find in the recently explored Huron Bay District, the finest clay-slates so far discovered in Michigan."† Within the Marquette district, he finds a carbonaceous shale more highly charged with graphitic material, "of a bluish-black color, but burns white before the blow-pipe, marks paper like a piece of charcoal, is soft and brittle, slaty in structure, and having a specific gravity of but 2.06."

"This rock has been found in the Marquette region only at two localities: 1. The S. C. Smith mine, T 45, R 25, where it seems to bound the iron ore formation on the northeast. 2. On the south side of Sec. 9, T. 49, R. 33, along Plumbago brook." Analy-

---

*See this occurrence described by the writer in *XVI Ann. Rep. Minn.* p. 180.

†This shale is recognized as identical with that occurring west of lake Gogebic.

sis gave professor Brush 20.86 percent carbon. "The analyses prove the material to have no commercial value, but possesses scientific interest as proving the existence of a large amount of carbon in the Huronian rocks. The equivalency of these shales with the members of the Marquette series has not been established; they are undoubtedly Huronian, and are, I suppose, younger than the ore formation XIII." (116.)

Major Brooks reported also, in a condensed way, on the Menominee Iron Range (pp. 157-182,) and very briefly, on the Lake Gogebic and Montreal river Iron Range (pp. 183-6). In connection with the latter, he presents a section showing the unconformable junction of the (so-called) Huronian with the (so-called) Laurentian. This is the same unconformity as has since been pointed out by Sweet, Irving and others.*

1879. Major Brooks, in 1879, made further publication of his views respecting the Menominee region, and particularly, that part of it which extends into Wisconsin.† Of his earlier Michigan work he makes the following memorandum:

"My reconnoissance of the northeastern side of the Menominee, the results of which are given in the Geological Survey of Michigan, vol. I, 1873, gave valuable data; but that work on the whole, was incomplete and crude, and will be superceded by this report, which is, however, not complete in several directions."‡

He recognizes the "Keweenaw (copper series)" among the rocks of his district. The Huronian, he states, is "known to rest nonconformably on the granite and gneissic rocks, regarded as of Laurentian age." [He is here understood to refer to the Penokee unconformity.] As to the Huronian, he claims to have succeeded in determining, in the Menominee region, the equivalents of his numbered groups in the Marquette region; and it will be useful to reproduce the essential parts of his table:

XX. *Granite, gneiss* and *porphyryte.*
XIX. *Mica-schist, hornblende-schist* and *gneiss.* Black, subcarbonaceous *slate* and *chloritic schists.*
XVIII. (Not observed.)

**Trans. Wis. Acad.*, 1875-6, III, 43-44; *Amer. Jour. Sci.*, 1877, III, xiii, 308. This Whitney and Wadsworth call a "supposed unconformability" (*Bull. Mus. Comp. Zoöl.*, vii, 495, 496, 497), adding that "the proof advanced was, that the foliation of the granite and gneiss dipped at a different angle from that of the Huronian rocks." * * "They have failed to observe the phenomena of contact, when seen, beyond the mere fact of a different dip to the foliation observed." Such too frequent rude contradictions might with more courtesy have given place to expressions of doubt; but, with more justice, to expressions of respect for the authority of such excellent observers.

†*Geology of Wisconsin*, vol. III, Pt. vii, pp. 429-459, with appended microscopical observations by Dr. Arthur Wichmann (of Leipzig), pp. 600-656, and Appendices, pp. 657-663.

‡*Geology of Wisconsin*, iii, p. 431.

XVII. Gray *gneiss* with small crystals of triclinic feldspar, and large ones of orthoclase. Associated with hornblende-chloritic-and micaceous-*quartz-schist*. The Commonwealth Iron horizon.

XVI. Schistose *greenstone*, with micaceous, chloritic, quartzose varieties. *Dioryte* (gabbro?).

XV. (Not identified.)

XIV. Light-gray, specular, conglomeritic *quartz-schist*, containing mica and magnetite.

XIII–VIII. (Not identified.)

VII. Gray and red, soft, unctous, *hydromicaceous schist*, graduating into *clay-slate*.

VI. *Iron ore.* Banded, quartzose, ferruginious *schist*.

V. *Dolomite marble* with cherty laminæ. Very thick and prominent.

IV and III. (Not identified.)

II. Lower *quartzyte*, massive to semi-schistose, arenaceous, in places micaceous and actinolitic, with occasional specular ore. Felch mountain supposed in this horizon.

I. Chloritic *gneiss*; hydrous-magnesian *schist*; *slate-conglomerate*; *quartzyte* and perhaps *dioryte*. (Possibly Laurentian.)

Comparing the Huronian rocks of different regions, Major Brooks reaches the following conclusions:

1. The Huronian rocks are generally rich in species and varieties, but the maximum of varieties is found in the Marquette and Menominee regions."

2. "The points of resemblance between the Marquette, Menominee, Sunday Lake and Penokee series are so numerous as to point, I think, unmistakably to their having been formed in one basin, and under essentially like conditions."

He adds:

"Those who are not disposed to admit that lithology affords much assistance in identifying rock-beds over even small areas, should have in mind that the Lower Silurian sandstone can now be seen quite uniform in character, over a much greater area in the same region. Almost the same remark may be made of the underlying Keweenian rocks. Cannot approximately as favorable conditions have existed for the formation of a particular kind of rock over a smaller area at the earlier period?"*

**Geology of Wisconsin*, III, 449-50.

NEWTON HORACE WINCHELL.

1873. The second season of the Geological survey of Minnesota found professor Winchell engaged in an examination of the geology of the Minnesota river. In describing the outcrops of the "Granites of the Valley," * he noted some features which, in his later researches have proved to possess great significance, the older observers either not having noticed them, or failed to inquire under what conditions they have been produced. This granite is the common ternary variety. In the neighborhood of Granite Falls, he says, in his description, "there are sudden changes in the rock, from real granite to hornblende schist. These occur irregularly." He speaks of the formation as having a dip, and supposes it due to original sedimentation.

1880. The ninth annual report† of the Geological survey of Minnesota contains "A Preliminary List of Rocks," 442 in number, collected by professor Winchell, on a tour made during the season of 1878, from Duluth along the north shore of lake Superior, to Pigeon point, and thence through the interior by the line of lakes and streams marking the international boundary, westward to Vermilion lake, and still thence to the Mississippi river. Both portions of the route had been previously traversed—the line from Grand Portage along the boundary, by Houghton, Norwood, the Canadian geologists, and a long succession of traders; but no previous explorer had gone with so settled a purpose to penetrate the mysteries of the off-shore geology; and no one had made its study the chief end of his visit. Norwood was on a hasty reconnoissance over an extended line; Houghton made a brief excursion as far as to Mountain lake and returned; and Bell passed over the route chiefly for the purpose of reaching the Canadian territories about the Lake of the Woods. The tour of 1878 was somewhat carefully studied, step by step. Not only were rock masses investigated petrographically and structurally, but the plans of the contours of the country, the systems of their building up, the great obvious movements by which juxtapositions and superpositions had been effected—these fundamental phenomena were all taken in by a broad sweep of observation, and the problems connected with them, if not at the time resolved, were placed in the midst of surroundings which continued thereafter to throw important light on them. It is worth the while to note some of the observations made—at the time, apparently isolated, but afterward wrought

---

**Second Annual Report of Minnesota*, 1873, pp. 160-176.

†*Ninth Report*, pp. 10-114.

into the great geological conceptions which seem now to represent much of the truth.

On the west side of Grand Portage, slate was seen which was probably the first recognition in Minnesota of the Animike formaion, isolated by Hunt in 1873, and of which so much was to become known. This is subsequently identified as the "silico-argillaceous slate" of Norwood. The "slate and quartzyte of Pigeon River Falls" are said to dip south. Numerous islands off the shore are visited. The principal rock-axis of Pigeon point peninsula, is, he says, "not evidently a dyke, but a massively bedded or coarsely jointed formation which extends west, and soon rises over fifty feet from the water, and shows a basaltic, mountain-like structure. It resembles the rock and structure of Rice point (near Duluth) and may be parallelized with it in age, and here is associated, as there, with a red, metamorphosed rock. Here, however, it is a part of the Animikie beds of Dr. T. Sterry Hunt, which would therefore seem to be only a downward extension of the Cupriferous series."

Proceeding as far as Mountain lake, he remarks "that these hills are all short monoclinals of gray quartzyte, with beds of argillaceous and black slate, dipping uniformly in a southerly direction, and covered with a greater or less thickness of the trap rock (gabbro?) of the country—the trap being sometimes one hundred feet thick, but generally less than fifty feet, and often the only rock seen, the lower beds being hid by the copious *talus*. The slate in some places has a dip slightly southwest, and the inclination amounts, usually, to about 8 or 10 degrees. The trap also dips with the slate, so that the hills have gradual slopes toward the south and steep slopes toward the north, or are perpendicular—indeed, they most frequently are perpendicular for about twenty-five feet from the top, or even one hundred feet, the trap having a widely basaltic structure, which causes it to fall away in perpendicular columns; the slate and quartzyte also, have frequent perpendicular jointage planes, which also facilitate the perpendicular breaking of the beds. The quartzyte is evenly and conspicuously bedded[†] without any confusion, but alternates, both gradually and suddenly with the black argillaceous slate. The most of it as far as seen to this place, is gray quartzyte. This quartzyte must be an immense formation, as it is that seen at Grand Portage, and all over Pigeon point, and the islands off the point."

---

[*] *Ninth Report*, pp. 69-70.

[†] The beds called here "quartzyte" are what the writer, in speaking of these formations, has styled interbeddings of "silicious (often jaspery) schist."

"Several important questions pertaining to the geognosy of this formation arise in an attempt to describe it, which must, for the present, remain unanswered, but which, perhaps, future examinations may solve:

1st. Is this trap older than the uplift of the hills, or did it come over the country when the uplift occurred?

2d. Are the dykes that are seen crossing this trap (as at the foot of South Fowl lake) of the same age as the trap, or are they subsequent to it?

3d. How much of the topography here is due to glaciation?

4th. Do the monoclinal hills run under each other, or are they each separate and isolated uplifts?

5th. Can these beds of supposed igneous rock be due to a change in the sedimentary rocks, instead of igneous outflow?

6th. Why is there an entire absence of amygdaloids?"

Arriving at the north side of Gunflint lake, he notes "hydromica (?) slate." "This rock rises in knolls and hills one above the other, irregularly disposed. The slates stand nearly vertical, running E. 20° N. This passes insensibly into the next," and "graduates back and forth." This resembles some forms of the slate at Thompson on the St. Louis river (p. 82). Belonging to the same formation is a "greenish, porphyritic rock (with albite ?), having an imperfect, schistose and fibrous structure, and some free quartz, embraced much like veins, in the slate. It is not vein matter, but gradually changes to the slate, right and left, the slates standing nearly vertical.

"This outcrop is supposed to belong to what the Canadian geologists have styled the Huronian. It underlies the quartzyte and Gunflint beds [now known as Animike slates] apparently unconformably. At least, it is another and distinct formation from the slates at Grand Portage" (p. 82).

It is to be regretted that this clew was not followed up. This is the discordance which has become celebrated.*

Coming to the characteristic black, silico-argillitic slate which gives name to Knife lake, he styles this rock "a light green, tough magnesian rock [which] can perhaps be designated a chloritic or serpentinous quartzyte," and recognizes it as belonging to the (then called) Huronian slate series; and thus, fourteen years ago, excluding it from the crystalline schist series, to which, later, it has been referred.

1881. A similar journey was made in 1879, and the results are found in the report for 1881.[*] The studies attending this trip were pursued under circumstances promising still larger results. The Knife-lake slates and the schists, now known as Kewatin, were identified near the west end of lake Superior. The tour extended to Grand Marais and Silver Islet, and from Grand Marais to Ogishke Muncie and the mouth of Poplar river. On Mayhew and Loon lakes he examined again, the "great quartzyte and slate formation, or the Animikie group." He describes again, and in more detail, the remarkably flinty breccia on the north side of Gunflint lake, and speculates on the cause of its condition.[†] I quote the following obscure paragraph:

---

*Compare also, p. 102 at bottom, and notice the curious speculation, p. 103. It is evident from this that it remains to discover flint and jasper beds in the Kewatin.

"The close proximity of this flint and jasper locality to the next great underlying formation (syenites and slates)[‡] makes it one of great interest to the geologist, but so far as scrutinized as yet, the true relations of the two formations are not revealed by anything here seen, though there seems to be an unconformability between them." (p. 88.) I have elsewhere quoted this passage as intimating an unconformity between the "slate and quartzyte" and the vertical schists north but further east, on Gunflint lake. But I am not sure this is the author's meaning, because he seems to be comparing the brecciated formation with the (underlying?) slates.

Coming to Ogishke Muncie lake, he subjects the mysterious conglomerate to further investigation. Notwithstanding the length of the passage, it may be well to quote largely, so that the reader may compare the statements with those of Sir William Logan in speaking of the slate conglomerate of Thunder bay (See p. 132.) He says:

"The conglomeritic character is hardly distinguishable on a fresh fracture of the rock, which sometimes shows different shades of green. But all over the surface, when glaciated and weathered, are visible the forms of rounded bowlders included in the rock, the different forms, colors and grain of the bowlders being brought out plainly. This is essentially the same formation as the rock 743 and 737, and it constitutes by far the greatest part of the country rock about Ogishke Muncie lake. Wherein the rock 737 differs from 738, which also passes into 744 by the accession of slaty structure, and the obliteration or modification of it by the accession of bowlders, it may be ascribed to varying proximity to, and influence of, the underlying 'talcose' rocks, in the process of deposition and metamorphism. * * On the island [Campers',] it is a real conglomerate, with a smoothly glaciated surface, and the sections of some of the rounded stones are a foot, and even more, in diameter. They are very abundant. Sometimes the rounded stones make three quarters of the whole rock, but in other cases, the slaty matrix is nearly free from them, over considerable areas."

---

[*] *Tenth Annual Report Minnesota*, pp. 9-122.

[†] *Tenth Annual Report Minn.*, p. 87.

[‡] The breccia locality is *within* the slates of the "Quartzyte and Slate" formation.

The author suggests the following order of superposition of the rocks in this part of Minnesota:

"1. The nearly horizontal quartzyte and slate formation composing the hills around the Grand Portage and the international boundary as far as Gunflint lake.

"2. The coarse grit or fine conglomerate, No. 738.

"3. The jaspery and calcareous beds that are known as the "Gunflint beds," Nos. 737, 743.

"4. The gray marble, No. 746. [See this further discussed in *XVIth Rep.* pp. 95-6.]

"5. The tilted slaty conglomerate, and the great conglomerate about Ogishke Muncie lake. Nos. 744, 750, 754.

"6. The amphibolyte and the chloritic slates, Nos. 731, 753, 348, 349, 350, 355, 356 and 358.

"7. Mica schists and alternations of mica schists and syenite. Nos. 335, 337, 339, 401, 406, 408, 414, 417.

"8. The syenites and granites of Saganaga and Gull lakes.*

"There is yet," he says, "one very important undetermined question relating to this generalized section, which ought to be borne in mind, viz: Is the great quartzyte and slate formation of the international boundary (No. 1 of this section) the same as the highly tilted slaty and quartzyte formation which passes into the great conglomerate (No. 5)? There are some considerations which seem to imply that it is, though in all descriptions and sections they have been treated as different terranes. (*a*) Where the horizontal slates approach the syenites at the east end of Gunflint lake, there is nothing to be seen of any beds representing the tilted slates. The syenites and their associated schists come on at once. (*b*) Where the tilted slates and conglomerates associated with them are traceable from the syenite upward to the gabbro, as south of Ogishke Muncie lake, there is nothing to be seen of any beds like the horizontal black slates of No. 1. (*c*) The "Gunflint beds" appear to belong to the horizontal slates of the international boundary at Gunflint lake, but their supposed equivalents[*] at Ogishke Muncie lake belong to schistose and tilted slates and conglomerates. (*d*) Although the horizontal slates and quartzytes of the international boundary strike west and southwest across the state, forming one of the most important topographical features of the northern part of the state, and can be followed for many miles as such, yet they are lost entirely in the region of the upper St. Louis, and the tilted slates are the only ones seen where that river cuts the rock at Knife Falls and below.[†] (*e*) The great gabbro belt which surmounts the horizontal slates along the international boundary, and prevails to the east and south of their line of strike, is seen to pass to the west of lake Superior, at Duluth, and to disappear from sight suddenly between Duluth and Fond du Lac, as if its continuance depended on the maintenance of the horizontal formation with which it is associated. (*f*) Where the Gunflint beds become jaspery hæmatite, as south and east of Vermilion lake,[‡] the structure of the tilted slates passes into the iron ore as if of the same formation. (*g*) The formation which underlies the Cupriferous at Fond du Lac is the tilted slates, and that which underlies it at Grand Portage is the horizontal slates."

---

*I venture to make, on these assignments, the following suggestions:

1. This clearly is the Animike.

2. This, I judge, is only a border condition of the Ogishke Conglomerate (See XVI *Ann. Rep. Minn*, pp. 313, 315). There are also, on the borders of Frog-rock and Town-line lakes, several occurrences of gravelly sericitic schist—as also on Ensign lake. (XVI *Rep.* p. 312, Rock 863; and p. 315, Rock 889, 890.)

3. I feel constrained to regard these as no distinct part of the Animike. (See XVI *Rep.* p. 251.)

4. This is what is described as a bed of dolomyte in XVI *Rep.* p. 316.

5. The Ogishke Conglomerate.

6. By this I understand the author to mean the later-called "Kawasachong rock"—green chloritic slates (even if originally erupted); the "greenstone" hills south and north of Ogishke Muncie, and the chloritic and amphibolitic conditions of the "Kewatin" seen in many places.

No separate place is assigned here to the vertical schists.

These suggestions in a very perplexing inquiry, may be very wide of the mark.

"A thorough examination of the hill-range between Gunflint and Ogishke Muncie lakes would probably reveal the facts as to any transition from the horizontal slates to the tilted slates."[§]

From some confusion noted in the stratification of the region south of Ogishke Muncie lake, the author seems almost ready to adopt the alternative afterward embraced by professor Irving.

In a paper embodying descriptions of fifty thin sections prepared from the rocks of the Cupriferous series of lake Superior professor Winchell pointed out distinctly the two-fold origin of crystalline rocks. He showed by demonstrations accompanying the memoir,[*] that the crystallizations resulting from metamorphism sometimes imitate closely the character and composition of the rocks whose eruptive escape has been the cause of the metamorphism. On the north of lake Superior, the contact of the gabbro with the red sandstone has produced "all stages of metamorphic change — from red sedimentary shale and sandstone to red felsite and syenite." A sedimentary rock heated to the point of fusion of the feldspathic constituents, and then cooled, will exhibit a non-differentiated ground, with feldspar crystals porphyritically disseminated. Heated completely to the fusing point and then cooled, the least fusible mineral — probably quartz, would first crystallize out, and later crystallizations would be penetrated by the older quartz. Simultaneously, the intrusive matter would impart certain constituents to the softened sedimentary bed, and minerals would arise for which the requisite constituents had not before existed in the bed.[†]

---

[*] It is not obvious that any such beds are there. But, in any event, if we distinguish the horizontal slates holding the "Gunflint beds" from the vertical slates holding the conglomerate, no difficulty will exist.

[†] From (*a*), (*b*) and (*d*), it is not to be inferred that two systems do *not* exist, but that they are not co-extensive. Their coëxistence is seen on the north shore of Gunflint lake

[‡] The very distinct hæmatite formation also contains jaspery beds.

[§] This journey was made in 1887. See *XVIth Rpcort*, pp. 79-89.

1884. At the Philadelphia Meeting of the American Association, he delivered an address before the Section of Geology as its president in which he discussed "The Crystalline Rocks of the Northwest."[‡] This was a broad survey in which he attempted to arrange the succession of the great Archæan terranes, and point out their relations according to the views of other geologists. As the table at the end contains a convenient synopsis of the positions taken that will be here first introduced.

---

[*] *Proc. Amer. Assoc.*, 1881, XXX, 160-6. Also *Tenth Ann. Rep. Geol. Minn.*, pp. 137-143. The subject was earlier discussed in *Proc. Amer. Assoc.*, 1880, XXIX, pp. 422-425, Comp. also, Tenth Rep., pp. 108, 111.

[†] The phenomena here referred to are of the same character as those which professor Bailey has since described and explained. See *Amer. Jour. Sci.*, III, xxxix, 273-280, Apr. 1890.

[‡] *Proc. Amer. Assoc.*, 1885, Pt. II, pp. 363-379; *XIIIth Minn. Report*, pp. 124-139; *Amer. Naturalist*, xviii, 984-1,000, 1884; *Science*, iv, 239-240, Sep. 12, 1884 (abbreviated.)

GROUPS.	EMMONS.	HUNT.	BROOKS.	IRVING.	Equivalents in Michigan.	Equivalents in Wisconsin.	Equivalents in Minnesota.
GROUP I. Granite and Syenite with Gabbro.	Hypersthene Rock. (Regarded as part of the Primary.)	MONTALBAN. Labradorian. Norian Upper Laurentian. Aronian.	Youngest Huronian.	Base of the Keweenawan.	XX	I and Ia. at Black River.	Duluth. Brulé Mountain. Misquah Hills. Beaver Bay.
GROUP II. Mica Schist.			The Huronian of Brooks. 1873.	The Huronian of Irving. 1870.	XIX at Marquette. XVII–XIX at Menominee.	XX–XXII at Penokee.	Little Falls. Pike Rapids. Outlet of Vermilion Lake.
GROUP III. Carbonaceous and Arenaceous Black Slate.	TACONIC SYSTEM, 1842-1846. Black Slate.	Animike.			XIV–XVII at Marquette. XV and XVI at Menominee.	VI–XVI at Penokee.	Animike. Black Slates. Grand Portage.
GROUP IV. Hydromica and Magnesian Slate.	Taconic Slate.				VI–XIV at Marquette. VI–XI at Menominee.	IV–VI at Penokee.	At "The Mission" Vermilion Lake. Vermilion Iron Mines.
GROUP V. Quartzyte and Marble.	Stockbridge Marble. Granular Quartz Rock.	The Huronian of Canada, 1855.			V at Marquette. II–V at Menominee.	I–III at Penokee.	Ogishke Muncie Lake.
GROUP VI. Granite and Gneiss with Hornblendic Gneiss.	Primary.	Laurentian.	Laurentian.	Laurentian.	Laurentian.	Laurentian.	Laurentian.

The author of this table comments upon his "Groups," in substance, as follows:

First Group. Is represented in Minnesota by the gabbro and red syenite at Duluth. * * The outcrop of red granite near New Ulm, lying under the conglomerate and red quartzyte, is probably in the southwestward line of extension of this group.

Second Group. Consists of schists that are micaceous and often staurolitic as well as garnetiferous. Variously associated with beds and veins of granite and gneiss. Has a maximum thickness of 5,000 feet.

Third Group. Sometimes passes into roofing slates, with beds of iron ore, quartzyte and dioryte. "Includes the black slates of the Animike group in northern Minnesota, of Knife lake, Knife Portage on the St. Louis river; and carbonaceous shales lately reported near Aitkin on the Mississippi river. Thickness, 2,600 feet.

Fourth Group. Schists soft and obscure, becoming quartzose and also hæmatitic; also with numerous beds of dioryte. In Minnesota, this is the iron-bearing horizon at Vermilion lake. Maximum thickness, 4,450 feet.

Fifth Group. Represented by No. V. at Marquette, Nos. II. and V. at Menominee, and Nos. I. and III. at Penokee. The marble lies above the quartzyte, and in the Menominee region has a minimum thickness of 1,000 feet; while at Marquette, it graduates into a dolomitic quartzyte of indefinite extent, the whole group being there essentially quartzyte. A most persistent and well-marked horizon. The quartzyte sometimes holds feldspar, thus having the appearance of granulyte. In Minnesota this horizon seems to run along the south side of Ogishke Muncie lake, near the international boundary, and includes perhaps the great slate conglomerate which is there represented. This seems to correspond to the lower portion of the great quartzyte of this group, and to be the equivalent of the "lower slate-conglomerate" of the typical Huronian in Canada. Normal thickness from 400 to 1,000 feet; but if the great conglomerate of Ogishke Muncie be included here, the thickness of this group in northern Minnesota will exceed 6,000 feet.

Sixth Group. In Minnesota, found on the international boundary, at Saganaga lake, and large boulders from it are included in the overlying conglomerate at Ogishke Muncie lake, showing an important break in the stratigraphy. Thickness unknown, but very great.

In the progress of the discussion, the author proposes to install the term "Taconic" in the nomenclature of the older rocks.

1887. The report of this year embodied views evincing positive progress in reference to several questions. The intimate relations of granitic rocks with terranes of admissibly sedimentary origin were brought into distinct view, and many instances of transition were pointed out,* and many remarkable cases of inclusion of granitic and gneissic fragments in the body of the schists, and vice versa. In the report, it was intimated that the Animike formation overlay one eruptive rock and underlay the other, and that it seemed to embrace the Ogishke Conglomerate in its lower portion (p. 381). The lower eruptive rock was represented to be, in some places, a remarkable agglomerate, and in various ways, to become changed to greenish schists, chloritic and sericitic, and to embrace in its mass, generally with an appearance of unconformity, the jaspilyte and iron ore of the Vermilion lake region. At the same time, this green rock exhibited, at times very manifestly, some signs of aqueous stratification. At other times, no such structure was found in it, and it merged into a dense, homogeneous, unbedded, doleritic mass. It was announced that the graywackes, which are in this "green-stone" formation, fade out by merging into its evidently eruptive condition; but in many places are distinctly sedimentary, having much quartz in rounded grains, arranged in unmistakable layers.

It was again pointed out that besides the large body of normal gneiss at the geological base of the series, there is inseparably associated with the gabbro, a red formation, having the apparent composition of syenite; and also a further distinction in the rock of the Giant's range — one portion of it being the result of local change in some bedded sediments probably later than the Laurentian (pp. 347, 349, 352, 353). The cause of this change in the sedimentaries was suggested to be the gabbro eruption. The red syenite resulting is the "red rock" of the earlier reports, the red quartz porphyry and the "Palisade rock" of lake Superior shore. This report contains a geological map of the northeastern part of Minnesota. The distinctions recognized are the following:

1. Trap and amygdaloid 2. Feldspathic sandrock	Cupriferous.
3. Gabbro and red granite, sometimes dioryte	Mesabi range.
4. Quartz porphyry and felsyte.	

Fifteenth Annual Report Minn., 1887, pp. 290, 292, 293, 294, 296. See also, the accompanying reports.

5.	Gray quartzyte and black slate	Animike.
6.	Greenstone, diabase and chlorite schist.	
7.	Sericitic schist, argillyte and graywacke	Kewatin (in part.)
8.	Iron ore.	
9.	Conglomerate and conglomeritic felsyte	Ogishke.
10.	Mica and hornblende schist with dioryte	Vermilion series.
11.	Gneiss, syenite, granite	Laurentian?

1888. Questions of taxonomy and parallelism occupy much attention in the report of work for 1887.[*] A visit to the "Original Huronian" of Sir William Logan leads to the conclusion that while the stratigraphic descriptions of Logan were faithful, the "green chloritic slates," so-called, are not by any means constituent parts of the stratigraphy, but are distinctly eruptive. The "slate conglomerate" of Logan, he thinks repeated in Minnesota, in the Ogishke Conglomerate (pp. 39, 58, 59.) The general parallelism is given as below.

CANADA.	MINNESOTA.
Ottertail quartzyte Thessalon quartzyte	Pewabic quartzyte? New Ulm, Pokegama and Wauswaugoing quartzytes.
Black slate	Animike black slate.
"Lithographic stone" and fine gray quartzyte	(Not known.)
Red felsyte	Felsytes at Duluth, and probably the great Palisades.
Missisagui quartzyte	(Not known.)
Slate conglomerate	Ogishke conglomerate.

Careful observations reported from the region north of Gunflint lake, indicate two conclusions:

1. There is a gradual transition, structural and mineralogical, from the Kewatin downward, through mica and hornblende schist, to the gneiss (pp. 68-70. Also *XVI Rep.*, 37-39.)

2. The intermediate crystalline schists (Vermilion group) do not seem in all places to be present (pp. 74-77, 81.) Room exists for the supposition that the metamorphic action in some regions was sufficiently powerful to carry fused masses of the lower sedimentary rocks bodily across the stratigraphic horizon of the crystalline schists into contact with the Kewatin schists. For this reason, crystalline schists sometimes are interrupted by gneissic rocks.

Of conglomerates in crystalline horizons, he says:

---

[*] *Sixteenth Minnesota Report*, 1888.

"The conglomeritic structure has therefore now been seen in the following crystalline rocks of Minnesota:

1. The Sauk Rapids "granite."
2. The porphyritic conglomerate at Ogishke Muncie lake, and the similar gneiss in Kekekabic lake.
3. The Stuntz island porodyte.
4. The greenstone of Twin mountain.
5. My brother reports it conspicuous in the Saganaga gneiss.
6. This bowlder [from Iron lake] shows it in the Vermilion group. (Later known in gneiss at Redwood Falls and Morton in the Minnesota valley.)
7. In the Laurentian syenite in Michigan, south of the Aurora mine.*

As to the distinctness of the Animike and Kewatin, the author entertains no longer any doubts, and he cites facts on pages 80 and 81 which prove it, and prove the equivalence of the Huronian of Canada with the Animike. But the upper part of the Ogishke conglomerate he is disposed to regard as a member of the Animike

In traversing the country between Gunflint lake and Ogishke Muncie lake he established the existence of an upper member of the Animike, which was named Pewabic quartzyte. It is magnetitic, and lies near the top of the Animike (pp. 85-86.) He parallelizes the Pewabic quartzyte with:

Wauswaugoning quartzyte.
Thessalon and Ottertail quartzyte (of Ontario.)
Potsdam sandstone of the Adirondacks.†

And these are regarded as further equivalents of the Pewabic quartzyte:

Granular quartz (Emmons)
Teal lake quartzyte, No. III (Brooks.)
Quartzyte group (Rominger.)
Baraboo quartzyte.
Sioux quartzyte (See XVIIth. Minn. Rep., p. 51‡.)

The following is the method of reasoning employed to establish the relations of the Ogishke conglomerate with the Animike:

"The hills about the northeast extremity of Gabimichigama lake consist entirely of Animike, fine-grained, tilted, fractured, recemented, but in general dipping northeasterly. At the lake shore, these beds weather out very rough, the silicious veins and the harder beds projecting. In some places they are about vertical, but they vary constantly in dip and strike."

---

*Many bowlders may be seen in the granite of which the Chicago "Auditorium" is built. According to the writer's observation, few granites can be found without evidence of fragmental intermixture. The granite in the "Auditorium" was taken from the Giant's range, at Hinsdale, Minn.

†On this parallelism see, also, *American Geologist*, March, 1880.

‡In the eighteenth annual report he concludes that the Pewabic quartzyte is below the black slates of the Animike, carrying with it the great gabbro outflow and the red granites and quartz porphyries to the same stratigraphic position.

"In passing along the north shore westward, however, N. E. ¼ of sec. 31, 65-5, this rock becomes slaty and vertical, and strikes N. W. by compass.

"All along the north shore, from the northeast end of the lake to about the centre of N. E. of sec. 31, 65-5, these titled slates and quartzytes extend, having a high dip toward the northeast, and finally becoming vertical. The shore-line runs across the strike but not at a right angle. Hence in going west, one passes onto lower and lower beds. At this place the Ogishke conglomerate appears on the shore, rising in a ridge about fifty feet high, at a few rods from the shore. On the beach it is disintegrated and hardly preceptible. The dip of the beds of quartzyte and slate that are interbedded with it is 88° N. E. and the strike N. W. *There is thus seen to be an undeniable graduation from the Animike into the Conglomerate.*" (pp. 90-91).

Further evidences of a transition are thought to be present in the disturbed condition of the strata about Fox and Agamok lakes (pp 94-95).

1889. This result, as announced above, is pronounced in the report of work for 1888[*] an important point reached—"the separation of the Ogishke conglomerate from the greenstone agglomerate, on which in some places it must lie unconformably. They seem to have both been affected by the gabbro epoch of disturbance and the gabbro was found in different localities to lie on the greatly inclined strata of one, and the nearly vertical strata of the other."

This report embraces very comprehensive discussions of the "parallels of the Kewatin," the "possibility of rocks younger than the Kewatin, before the beginning of the Taconic," the "age of the Taconic (Animike Huronian)," and the "age of the Potsdam," all of which must be consulted in arriving at an adequate estimate of aggregate results reached by the author; but it is necessary here to avoid prolixity. Among "problems that need further investigation," the following themes are suggested: Eruptive and sedimentary Laurentian; Planes of hydrothermal fusion, and their relation to the origin of the crystalline rocks; Date of upheaval of the crystalline schists; Nature and origin of jaspilyte; What is muscovado rock ?

---

[*] *Seventeenth Annual Report, Minnesota,* p. 24. 1888.

Toward the close of the report, the following general table of Minnesota rocks is introduced:

CALCIFEROUS. Magnesian limestones and sandstones. ST. CROIX. Sandstones and shales.	Dikelocephalus horizon.
Overlap unconformity.	
POTSDAM. Quartzyte, gabbro, red granite and Keweenawan.	Paradoxides horizon.
Overlap unconformity.	
TACONIC. Black and gray slates and quartzytes, iron ore (Huronian, Animike).	Olenellus horizon.
Overlap unconformity.	
KEWATIN. (Including the Kawishiwin or greenstone belt, with its jaspilyte), Sericitic schists and graywackes. VERMILION. (Coutchiching?) crystalline schists.	Archæan.
Eruptive unconformity.	
LAURENTIAN. Gneiss.	

CARL ROMINGER.

Dr. Rominger's observations and speculative opinions in reference to the older rocks are embodied in a state report upon the Marquette and Menominee iron regions of the Upper Peninsula of Michigan.* Taking up first the Marquette iron district, he conceives it "as a synclinal trough of granite, which by the upheaval of its northern and southern margins, caused the inclosure of the incumbent sedimentary strata between its walls, and their simultaneous uplift and corrugation into parallel folds by the lateral pressure exerted from its rising and approaching edges" (p. 4).

Speaking more specifically, he says of the two series hitherto regarded as Laurentian and Huronian :

By comparing the descriptions of the Laurentian formation as developed in Canada, with the granitic exposures observable in Michigan, or specially in the Marquette district, I cannot see so strong an analogy between them as to identify them without hesitation ; while I endorse the identification of the other group of rocks with the Huronian, although they differ too, in some degree" (p. 5). "I declare at once my serious doubts whether the granites of the Marquette region represent the Laurentian series of Eastern

---

**Geological Survey of Michigan, Upper Peninsula*, 1878-80, accompanied by a Geological Map, vol. iv, 8vo., pp. 248, 1881.

Canada, which I have never had an opportunity to study in the field, but which is represented to be a much older formation, preexisting as the surface rock before the Huronian sediments began to form, while, according to my own observations, the granites of Marquette are eruptive masses, which came to the surface after the Huronian beds were already formed."

Referring to the discordances between these two systems, frequently alleged by the Canadian geologists, he says:

"As far as my observations go, I have never been able to discover any positive proof of an existing discordance."

Further, in reference to the successional and structural relations of the series, he continues:

"By their eruption, [the granitic rocks] caused not only the great dislocations of the Huronian formation, but the half molten, plastic granite mass induced by their contact with the Huronian rock-beds, also their alteration into a more or less perfect crystalline condition, and commingled with them so as to make it an embarassing task to find a line of demarkation between the intrusive and the intruded rock-masses. The syenitic and gneissic hornblende rocks connected with the granite differ so little from the crystalline hornblende rocks of the Huronian series, that I look at them merely as differently advanced stages in the transformation of the same material. Those nearest to the focus of altering influences are now completely transformed and restored to the domain of the volcanic nucleus; the more remote strata were less changed, and retained distinct marks of their sedimentary origin; but if this view is correct, it cannot be expected to find traces preserved of the conformable or non-conformable deposition of the Huronian layers on their substratum" (pp. 6, 7).

He dissents from the subdivisions of major Brooks.

"Beginning below with his groups from I to V, he never made an attempt to define them. * * As to groups VII, IX and XI, certain dioritic outcrops are designated and considered to be regularly interstratified layers in the sedimentary succession, while I have full reason to consider them as intrusive masses, belonging to a lower horizon of the Huronian series, which by volcanic pressure have been forced through or between the incumbent rock-beds wherever a chance for it was offered, and consequently are found, one time in contiguity with this, another time with another stratum as it happened to be the surface rock of the spot. * * Groups XV to XX, intended to comprise a younger series of beds developed in the western part of the Marquette region, are unnecessarily multiplied into vaguely defined subdivisions. Major Brooks identified strata of the Menominee river district as representatives of Groups XV to XX which, lithologically, have no similarity with those of the Marquette district, adding still more to the confusion already existing." Dr. Rominger arranges the Huronian series in the following subdivisions (p. 8).

VI. Mica Schist Group.
V. Arenaceous Slate Group.
IV. Iron Group. [Quartzite Group (p. 71.)]
III. Quartzite Group. [Iron Group.]
II. Dioritic Group.
I. Granitic Group.

The Serpentine group is separately considered.

Before the completion of his report, Dr. Rominger became convinced that his Iron group and Quartzite group ought to exchange places, as shown above in brackets.

Besides the granitic masses bounding the Huronian on the north and south, he says:

"Granites are also found interstraified with the Huronian schists."

Of the character of the granite he says:

"They are usually middling coarse grained, of reddish tints, often composed of a magma of incompletely defined crystals imbedded within a granular interstitial mass rather than of well-formed, completely defined crystals; its fracture is therefore rather generally of a dull lustre. * * The micaceous constituent of these granites, where it does enter into the composition, is rarely well crystallized in brightly shining larger leaves, although it occurs occasionally, but usually has a minutely scaly form and a dark green color approaching to chlorite by gradations, or is replaced by hydromicaceous, fibrous, granular substance, generally called talcose from its soft greasy feel and its lighter color, with partial transparency in thin seams" (p. 15).

In describing gneissoid rocks of this region he says:

"This stratified banded rock, in contiguity with the granite, and alternating with it in parallel belts, often becomes completely entangled with it. The granitic masses intersect the gneissoid, enter wedge-like between them in the direction of the lamination or transversely, inclosing strips of the gneissoid ledges between the loops of the anastomosing granite seams, and, moreover frequently the so intermingled masses are curved into the most curious coils and serpentine flexions, which evinces their almost plastic condition at the time their intermixture took place." (pp. 16, 17.)

Passing to the consideration of the Dioritic group, and repeating his conviction that the granites are the newer, he says:

"One may ask, of what nature, then, was the substratum on which the Huronian sediments were deposited? I answer: Nothing contradicts the possibility of their deposition on a surface of granite already formed; it is even probable to me that it has been so; but, if we reflect upon the high degree of plasticity, and the almost perfect liquefaction which the concerned rocks subsequently underwent, and upon the dislocative forces causing the softened, and necessarily by this softening process, considerably altered, masses to intermingle almost chaotically, we can no more wonder that the traces of the originally existing former relative position of the rocks among themselves are greatly obliterated. The records of these periods in the history of the earth's crust, when oceanic sediments commenced to form, and fell back again within the grasp of the central fire-focus, as we can observe it in this case, are wiped out, and most likely all our efforts to ascertain the existing original conformity or discordance between such rocks will be in vain" (pp. 22, 23).

"The rock series comprised under the name of *Diorite Group* is made up by a large succession of schistose beds of a very uniform character, which are interstratified with massive belts of diorite differing in structure from the minutely granular, almost aphanitic condition, to a coarsely crystalline form, and being in chemical composition almost identical with the schistose beds" (p. 23).

Certain relations of the dioritic masses and contiguous schists are of interest:

"Often we see, as in the above mentioned instances, the schists adjoining a diorite mass completely entangled with it, in a mode which proves a high degree of plasticity of the diorite mass at the time intermixture took place. * * Although the general character of this large series of rock-beds is very uniform, as it regards the chemical composition, still, an endless number of variations in their structure is produced by the different degrees of metamorphism to which these once indubitably sedimentary rock-beds were subjected" (p. 34).

It will be remembered that major Brooks had admitted the existence of two horizons of iron ore. This was because at Negaunee and the vicinity, a quartzyte was found in a relation of infraposition to the ore-bed, while in most of the mines of the district, a quartzyte was seen reposing above the local ore-bed. These phenomena were supposed to indicate the existence of an ore-bearing horizon above the quartzyte and another below it. Dr. Rominger undertakes to prove that only one ore-horizon exists, and that the normal position of the quartzyte is above. Major Brooks was also under the necessity of assuming two quartzytes, Nos. XIV and V, the latter, or Teal lake quartzyte, being, according to Rominger, identical with the former, and its actual relative position being "the result of an overturn of the strata." (pp. 71, 72, 89.)

Lithologically, he adds:

"The quartzites covering the ore-bearing ledges are compact, dark-colored by hæmatitic pigment and by intermingled granules of martite. The inferior strata are almost regularly brecciated and intermingled with ore-fragments. In the pits of the Cleveland mine, south of the Houghton and Ontonagon Railroad, these brecciated quartzites are immediately underlaid by a fine seam of specular ore which itself, is on its surface, of brecciated structure. This ore-bed is underlaid by a series of light greenish or grayish colored, silky-shining, hydromicaceous schists impregnated with small martite crystals, which on their part, repose on the red, jasper-banded lean ores with inclosed seams of granular and slaty specular ore. In the pits north of the railroad, the quartzite is generally underlaid by chloritic schists inclosing locally quite large octahedrons of martite. Below them usually follows a valuable seam of specular ore, schistose chloritic beds again, and then mixed, jasper-banded, lean ores, with other interstratified seams of ore, partly in the granular form, partly as a slate-ore; lowest, resting on dioritic schists are, in the New York mines, fine-grained, silky-shining, dark, gray-colored argillites, charged with minute granules of martite more or less abundantly," (pp. 81-82).

The "*Arenaceous Slate Group*" of Rominger is generally incumbent on the quartzyte formation; but where this is wanting, it rests on the iron ore formation; and if this also is absent, it rests directly on the dioritic series. According to these statements a break exists between the epoch of the quartzyte and that of the Arenaceous Slate (Compare also, pp. 113, 114, 115.) These strata appear sometimes as "a thick belt of black, fine-grained, slaty rock-beds, interlaminated with silicious sandy seams. * * Next south of these slates are high walls of massive, light colored quartzites in direct conformable contact with them," (p. 105).

In other localities, the group "consists of sandy, somewhat micaceous flagstones, or of finer-grained, banded, silicious rock-beds all more or less impregnated with protoxide of iron as a coloring-matter, and with granules of magnetite, (p. 108). Elsewhere they are clay-slates more or less silicious, (pp. 112, 113); or "black magnetic flags interlaminated with slaty and arenaceous seams," (p. 117).

At a locality in the valley of the Carp river this series has "in part, a conformable northern dip with the quartzites, but frequently also, a southern dip is observed; though the direct contact of the two formations" is concealed by Drift, (p. 106).

This Arenaceous Slate group occupies the surface over a large area on the north of the dioritic belt which abuts on lake Superior at Marquette; and over another area on the south of the dioritic belt. It is believed by Dr. Rominger to be of the same age as the slate formation in the district of L'Anse and Huron bay, between Marquette and Keweenaw point. *The thickness of the latter slates "is enormously great." In color they range from dark to blackish, are partly hard and silicious, of bedding and cleavage too irregular for roofing, but are also in part, regularly laminated, of an agreeable black color, and well suited for roofing, (vol. iii, p. 163). Locally, however, the Huron slates vary to "whitish-gray-yellow, red and brown." They possess all degrees of hardness. The cleavage appears often coincident with the sedimentation, but where the colored bands are preserved, they are seen to make an acute angle with the cleavage. The sedimentary dip is northward. The formation presents three divisions: An *upper* of lighter colored, variegated slates; a *middle*, of alternating slaty and arenaceous beds, with interstratified, larger, compact quartzyte belts of light color and partly blackish; and a *lower* division embracing the roofing-slates, (vol. iv, p. 130). The middle division is regarded as equivalent to the Arenaceous Slate group of the Marquette district. It is likewise an instructive coincidence that a higher horizon of iron-ore occurs in both regions, of which the Taylor mine is an example in the L'Anse district, and the Northampton and d'Alaby mines (north of the Champion mine) are examples within the Marquette district. The ore occurs above the black slates, which in the Marquette district are graphitic. These ore deposits are regarded as contemporaneous with that of the Commonwealth mine in Wisconsin† (pp. 130, 222-227).

The rocks of the Mica Schist group of Rominger are described as "a sub-porous ground-mass of very minute granules of white, translucid quartz in intermixture with a large proportion of bright-

---

*Dr. Rominger's earliest observations on the L'Anse slates are found in *Geology of Michigan*, vol. iii, pp. 150-166. His later views are in vol. iv, pp. 129-130.

†This is the view of major Brooks, recorded ante' p 174. The reader cannot fail to compare the description of these slates and their accompaniments of quartz-schist and iron-ore, with the published descriptions of the Animike series. See, especially, ante' pp. 176-184. For further description of the Commonwealth mine, see C. E. Wright, *Geology of Wisconsin*, vol. iii, pp. 678-684. Compare also. Eagle mine, Wisconsin.

ly glistening black mica scales, and not rarely also, with chlorite" (p. 131).

The mica is sometimes silvery, and the schists are interlaminated with large belts of a more compact, minutely granular, sub-porous quartz rock, not so rich in the micaceous constituent, but often mingled with curved greenish crystals of actinolite.* In some conditions this formation reveals a distinct sedimentary striation (pp. 132, 133).

Dr. Rominger is not able to reach a satisfactory solution of the genesis of the Serpentine group.

"The hypothesis that the Serpentine formation is the product of local metamorphic influences on the dioritic series [by which it is surrounded], is very improbable, as the lithological character of the two contiguous rock-species changes abruptly." "The rocks occur generally in bulky, non-stratified masses which, if they ever originated from mechanical sedimentary deposits, are by chemical action so completely transformed as to efface all traces of their former detrital structure. They resemble a volcanic eruptive rock, forced to the surface in a soft plastic condition; and most likely heat was one of the prime agents in their formation, or else transformation in combination with aqueous vapors—which is suggested by the hydrated composition of the serpentine" (p. 135).

A study of the Menominee iron district led to the determination of the following groups of rocks (p. 182).

III. *Lake Hanbury Slate Group.* Dark-gray, slaty or schistose beds, with interlaminated quartzose belts. Thickness over 2,000 feet.

II. *Quinnesec Ore Formation.* In the *upper* part, light red, whitish or gray, hydromicaceous and argillitic strata. In the *lower* part, silicious beds richly impregnated with iron oxide in the amorphous, hæmatitic condition, or in the crystalline form of martite, with metallic lustre, and inclosing beds almost exclusively of martite granules. The valuable ore deposits. 1,000 feet.

I. *Norway Limestone Belt.* Light-colored quartzyte and silicious limestone, usually in part of a brecciated structure. 1,000 feet.

The rocks along the Menominee river are regarded as equivalents of the Diorite Group of the Marquette district, and decidedly *not* representatives of Nos. XV–XX of major Brooks.

---

*Evidently this is not a proper "mica schist," but rather a micaceous quartzyte or a micaceous quartz schist. It can scarcely be compared with the "tender" mica schists of Hunt's Montalban, though the horizon is nearly coincident.

In general, the comparison of the Marquette and Menominee districts, in spite of Dr. Rominger's deprecation of tabular parallels, may be best shown by the following table (pp. 240-241):

	MARQUETTE.	MENOMINEE.
V.	Ore deposits of the Taylor, S. C. Smith, d'Alaby and Northamton mines. Actinolite schists above quartzytes of Michigammi and Spurr mines.	Commonwealth and related ores. Actinolite schists.
IV.	Quartzyte Group (Teal lake). Limestone in juxtaposition.	Quartzyte of Sturgeon river falls. Limestone separated by an interval.
III.	Iron Group.	Quinnesec Iron range.
II.	Dioritic Group. Intrusive Granites.	Diorytes and schists of Menominee river. Felsyte Porphyry, Pemenee Falls.

ROLAND DUER IRVING.

1877. In his annual report for 1874, made to Dr. I. A. Lapham, state geologist of Wisconsin,[*] the "Copper-bearing Rocks" were made by professor Irving, a distinct division in the geology of the northern part of the state, holding a position between the Huronian and the Potsdam sandstone. He showed also the existence of a synclinal axis in Wisconsin, in continuation of the great trough between Keweenaw point and Ile Royale.[†] He held, *first*, that the beds of the Copper-bearing series and those of the Huronian were once spread horizontally over one another, including the whole series of tilted sandstones on the Montreal river; they were disturbed by the same force, and receiving their present tilted positions at the same time, as evinced by the entire conformability of the two series. *Second.* The horizontal sandstones of the Apostle islands and the west side of lake Superior were laid down subsequently, and after an immense amount of erosion; and the sandstones of eastern lake Superior were formed at the same time. *Third.* The Copper-bearing rocks should rather be classed with the Archæan than with the Silurian.

The Baraboo and related quartzyte masses lying in Wisconsin, many miles south of the principal Archæan area, have been differently viewed by different geologists, some regarding them as of Huronian age,[‡] and others, as the representatives of the Potsdam sandstone,[§]—the Wisconsin sandstone so described, pertaining as they think, to a higher horizon. Professor Irving, as early as 1871, announced his conviction of their Huronian age; and in the Wisconsin report, he worked out the evidences with fullness. The quartzytes are differentiated from the contiguous sandstone by lithological characters and abrupt structural unconformability; and the only weakness in professor Irving's position is the lack of full proof that the sandstone is the true equivalent of the Pötsdam.*

---

[*] *Geology of Wisconsin*, Survey of 1873-1877, vol. ii, p. 47, 1877.

[†] This view was earlier set forth in *Amer. Jour. Sci.*, III, viii, 45-56, 1874.

[‡] J. Hall, *Geology of Wisconsin*, 1862; Irving, *Amer. Jour. Sci.*, III, iii, 93-99; *Geology of Wisconsin*, ii, 504-524; Chamberlin. *Geol. Wis.* ii, 248-256.

[§] Percival, *Annual Report Geol. Surv. Wis.*, 1856. p. 101; A. Winchell. *Amer. Jour. Sci.*, II xxxvii, 226; J. H. Eaton, *Wiscon. Acad. Sci.*, Feb. 1871.

1880. The third volume of the geology of Wisconsin reveals his masterly grasp of the geological structure of northern Wisconsin, and of the genesis and history of the rocks which underlie the region. Here are presented in bold and confident outline, those interpretations, bordering sometimes on speculation, which characterized the leading discussions which occupied him until removed by an early death. His writings are so voluminous, however, that it will not be practicable to do more than set forth his positions on some of the great questions with which he grappled.

In reference to the nature and origin of the Laurentian rocks, which he fully parallelized with the Canadian Laurentian (iii, 5), we find him using the following language:

"The prevailing rock along the northern border [of the northern mass] is a dark gray to black hornblende gneiss, in which the hornblende has usually been more or less altered to chlorite. This alteration, when carried to any considerable extent, gives a greenish tinge and greasy feeling to the rock, and in cases of extreme alteration, there is a passage to a green chloritic schist. The associated granites are usually light pinkish-tinted to gray, and highly quartzose, a frequent gneissoid tendency showing their sedimentary nature," (iii, 6).

"The hornblende gneiss is always very plainly laminated, frequently highly schistose and the whole internal structure of the rock, as seen under the microscope, shows conclusively its original clastic condition. The granites are generally without such distinct bedding but appear nevertheless, to be true metamorphic granite. No eruptive granite, recognizable as such, has been observed. It is not possible, without overstepping the limits of our district, to reach any important generalizations with regard to the Laurentian series. It is evident enough that the rocks are of a true sedimentary origin, and that they have been folded in an exceedingly intricate manner," (iii, 93).

In still another place, professor Irving records views in this connection, which possess interest:

---

*This equivalency has been earnestly contested in writings by N. H. Winchell, already quoted. See. anté, pp. 175.

"The term igneous, as used by Mr. Wright, who seems also to hold to the unwarrantable theory that the original rock of the earth's first formed crust would be granite, is one not applicable to any granites, since even in the case of the exotic kinds, the relation of the constituent minerals disproves a true igneous origin. The quartz of granite is always the last formed mineral, whereas, from its infusibility, it would certainly be the first to form in cooling from a state of fluidity. All the facts go to show that the intrusive granites are but sediments softened by what has been termed aqueo-igneous fusion, to a degree of plasticity sufficient to allow of their penetrating fissures in the adjacent formations. The intrusive or exotic granites and the metamorphic or indigenous granites have thus had about the same origin, and there are no lithological characteristics whatever, either microscropic or macroscopic, by which we can distinguish them in specimens," (iii, p. 194, note).

At a later date, professor Irving recorded his views as follows:

"This stratification [of gneiss], or parallel arrangement of its ingredients, is commonly believed to have been caused by the process of sedimentation, the crystalline texture now shown by the gneiss and all other crystalline schists being regarded as the result of a peculiar process of molecular arrangement known to geologists as 'metamorphism.' While it seems very probable that there is a great deal of truth in this view, the theories of metamorphism as they now stand, are very unsatisfactory. Many rocks which have been called metamorphic are plainly of an eruptive origin, and it seems not improbable that the same origin is to be attributed to some rocks with a strongly developed schistose structure." *

Of the Huronian system he remarks:

"Lying immediately against the Laurentian, and very sharply defined from it, we find, extending from the Montreal river westward for fifty miles, to lake Numakagon, a belt of schistose rocks which we refer unhesitatingly to the Canadian Huronian, and which are beyond question, the direct westward extension of the iron-bearing series of the Upper Peninsula of Michigan," (iii, 6).

The subdivisions of this belt are recognized as follows, (iii, 6):

5. Medium-grained to aphanitic, dark gray mica schists, with coarse intrusive granite. 7,985 feet.
4. Alternations of black mica slate with dioryte and schistose quartzytes, and unfilled gaps. 3,495 feet.
3. Tremolitic magnetite schists, magnetitic and specular quartzytes — forming the Penokee Iron range. 780 feet.

**Geology of Wisconsin*, vol. i, p. 352, 1883.

2. Straw-colored to greenish quartz-schist, and argillitic mica schist, often novaculyte. 410 feet.
1. Crystalline tremolitic limestone, at times overlaid by a band of white arenaceous quartzyte, and at times absent, the next formation above them coming into contact with the Laurentian. 130 feet.

As the identification of the Penokee series with the Huronian is still a subject of debate, professor Irving's affirmative reasons possess interest:

(1). There appears to be a direct continuation with the iron-bearing system of the Marquette region of Michigan; (2). The grand subdivisions of the Bad river [Penokee] and Marquette systems are strikingly similar;[*] (3). The Bad river and Marquette systems both show the same relation to the Laurentian and Keweenawan systems as found in the Huronian of Canada; i. e. are newer than the former and older than the latter; (4). The Marquette system is found in unconformable contact with the Lower Silurian red sandstone of lake Superior, and also in the Menominee region, is also found in unconformable contact with the fossiliferous Primordial sandstones of the Mississippi valley (iii, p. 7).[†]

The boldest feature of the views promulgated at this time, was the characterization of the "Keweenawan System," a step foreshadowed in 1877, and evidently meditated since 1874. This widely extended Michigan-Wisconsin system is thus described:

"It is a distinctly stratified system, but is in large measure made up of eruptive rocks in the form of great flows. These appear to constitute in Wisconsin, the lower ten thousand to thirty thousand feet of the system, apparently without interstratified detrital beds. Above these, we find the detrital beds increasing in frequency, until they seem to exclude the igneous rocks altogether; the upper portions for some fifteen thousand feet, being apparently composed wholly of sandstone and shale, with a heavy mass of conglomerate at base" (iii, 7).

These rocks in northern Wisconsin, form a true synclinal depression, and the Chequamegon bay lies within it, but crowded over to the northern side. The eruptive rocks of the system are chiefly of the augite-plagioclase kind—hornblende when occasionally occurring, being always a paramorphic product of the augite. These eruptives, therefore present a marked distinction from the hornblende-bearing eruptives of the Huronian ; and belong to the Rosenbuschian categories, diabase, melaphyr and gabbro. The diabases, which are far the most abundant, occur in distinct beds of overflow, each of which (as first pointed out by Pumpelly and Marvine) is amygdaloidal above, and massive, often columnar below, with an intermediate zone, which Pumpelly designated "pseudo-amygdaloidal." The gabbros are coarse grained, and two varieties are distinguished, the most common being light to dark gray and perfectly crystalline, and the other being red and black mottled, or red and gray mottled, with some of the crystals dulled in appearance, or red-stained by iron infiltration (iii, 10).[*]

---

[*] The stratigraphy of the Penokee Range is given in *Amer. Jour. Sci.* III, xvii, pp. 394-395 and *Geol. of Wis.*, iii, p 450, table, and in full detail in the same volume, pp. 103-166. On the "Mica Schists and Black slates," see Van Hise, *Amer. Jour. Sci.*, III. xxxi, 453-459, 1886. On the "Iron Ores" of the series, see Van Hise, *Amer. Jour. Sci.*, III, xxxvii 32-48, 1889. On their "Origin" see Irving, *Amer. Jour. Sci.* III, xxxii 255-272, 1886.

[†] This identification had been announced previously by Irving in *Amer. Jour. Sci.*, III, xvii, 393-398, 1879. Further on the "Divisibility of the Archæan in the Northwest," see Irving, *Amer. Jour. Sci.*, III, xxix, 237-249, 1885.

1883. In the progress of these studies, professor Irving devoted much attention to the subjects of paramorphic changes and secondary enlargements in the mineral constituents of rocks; and while not by any means the first to bring these facts to light, he was foremost in extending our knowledge of them, and in illustrating their importance in the history of the rocks. He alludes to the fact that most of the older, dark basic, massive rocks have been called diorytes, because hornblende is joined in them with a triclinic feldspar, while augite seldom occupies the same place. But he says:

"Precisely the reverse of this is the case, the diabases, in fact, being the common kinds, while diorites are everywhere rare. Moreover, in many diorites entitled to be so called by their content of hornblende as a chief constituent, this mineral has been proved to be merely a secondary transformation of augite, remnants of which are here and there to be seen in little cores." [†]

This, he says, is true of all the diorytes which he had studied in this section, and he entertained little doubt that the same would be found true of the diorytes described by Wichmann from the Menominee region. Hence he concludes that no dioryte as an original rock, has been found in Wisconsin.[‡]

The work on the Wisconsin survey having closed, professor Irving entered upon a great undertaking, under the auspices of the United States Geological Survey. This was the preparation of "a memoir aiming at a general exposition of the nature, structure and extent of the series of rocks in which occurs the well-known native copper of lake Superior." The transmission of this memoir bears date October 25, 1881, but the title page is dated 1883.[*]

---

[*] This series of beds had in 1873 been named "Keweenaw Group," by T. S. Hunt, (*Trans. Amer. Inst. Mining Eng.*, 1, 331-342); and in 1875, "Keweenawian," by Brooks. Later "Keweenian," the more euphonious form of the name, was proposed by Hunt (Harper's *Annual Record*, 1876). See *Geol. Wis.*, III. 660. Removing superfluous letters, there remains "Kewenian," the best form of all.

[†] *Geology of Wisconsin*, vol. 1, p. 345, 1883.

[‡] What is true in Wisconsin is very likely to be true also in Michigan.

This remarkable work is an amplification of views, and strengthening of positions relating to a newly recognized geological system which in the Wisconsin report had been defined as Keweenawan.[†] It is not intended to give any synopsis of this volume, nor to point out the excellencies of the treatment; but a few of its more important positions will be stated.

The Lower Group of the Upper Copper-bearing series of Logan —the "Animike" of Hunt—is excluded from the system; but the white and red dolomitic sandstones, in the peninsula between Black and Thunder bays, and thence to lake Nipigon, are included. The horizontal sandstones which form the south shore east of Bete-Grise bay on Keweenaw point, and westward from Clinton point, Wisconsin, are also included. The system, then, "consists of the succession of interbedded traps, amygdaloids, felsitic porphyries porphyry-conglomerates and sandstones, and the conformably overlying thick sandstone, as typically developed in the region of Keweenaw point and Portage lake, on the south shore of lake Superior," (pp. 24, 385).

The volcanic theory of the origin of pebbles forming the conglomeritic beds is combatted. This theory had been promulgated by Houghton in 1841, and Foster and Whitney, in 1850 and 1854.[‡] The system is demonstrated to be unconformable with the Huronian below and the Silurian above.

The possibility of a sedimentary origin for any of the stratified semi-amygdaloids[§] of the Agate Bay group of beds is "absolutely excluded by the completely crystalline interior texture, the highly vesicular character, the presence of unindividualized magma, the microscopic flowage structure, and the graduation of each bed downward into vertically columnar, non-vesicular olivine-diabase,

---

[*] *U. S. Geological Survey*, Clarence King, Director. "The Copper-bearing Rocks of Lake Superior," 4to, pp. 464, with maps and cuts, 1883. [Being Monograph V.] A full digest of this memoir is contained in the *Third Annual Report* of the U. S. Geol. Surv. pp. 93-198. *Bulletin No. 23, U. S. Geol. Surv.*, 1885, pp. 124, by R. D. Irving and T. C. Chamberlin, is an important supplement to this memoir.

[†] This system is set forth in an elementary way suitable for the general reader, by T. C. Chamberlin, in the first volume of the *Wisconsin Report*, pp. 96-118, 1883.

[‡] Wadsworth also states that Foster and Whitney "remain the best and most accurate exponents of the geology of the country." (*Bull. Mus. Comp. Zool.*, vii *Geol. Ser.*, 1, pp. 13, 131); and would thus seem to approve this leading position; yet, without noting his divergence from them, he says: "These conglomerates and sandstones show by the rounded and water-worn character of their constituent pebbles and grains, that they are beach deposits," (*id.*, p. 128).

[§] Noticed by N. H. Winchell, anté, p. 177, and called by Norwood, "metamorphic hales."

(pp. 138, 287)*. The forms of the "Sawteeth mountains" he refuses to attribute to faulting, and says:

"The case is just such as is found in every region of flat-dipping, hard rocks, and especially where softer layers are interbedded, as in this case," (p. 142).

He regards the dikes seen along the Minnesota shore as sources of the flows of the lake basin; and antagonizes Dr. Selwyn's suggestion of activity through a single vent (p. 144). The "Palisade rock," he says, "is shown under the microscope, to be a quartz-porphyry, with no traces of a clastic nature (p. 187). The central mass of the Porcupine mountains is a quartzose porphyry unquestionably eruptive. Their structure has so much in common with that of the laccolitic mountains in southern Utah, that they might be supposed to owe their existence to an eruption of the porphyry of their central portions. * * But these mountains, he concludes, "owe their existence, in all probability, to a fold, the porphyry of the central portions being one of the usual embedded masses laid bare by subsequent denudation" (pp. 150-1).† He takes the position, and repeats it many times, that the so-called Animike slates are "beyond question, the equivalents of the iron-bearing Huronian of the south shore" (p. 157).

Of the "red rocks" so largely associated with the gabbro of Duluth, he says:

"They lie in it very irregularly, and form nothing like distinct belts, so far as I could make out. They may be seen in great patches hundreds of feet square, and surrounded on all sides by the gabbro, and again, as at the quarry near Rice's Point, in irregular series, from two or three inches to several feet in width. Much the most abundant kind of these red rocks is one which presents macroscopically a wholly crystalline texture and a pinkish color mottled with green. Pink feldspar facets, now and then striated, quartz, and a greenish mineral, may all be made out with the naked eye. Under the microscope, the rock is seen to be chiefly composed of reddened orthoclase; greenish hornblende, quartz and magnetite are also present. The quartz occurs both in quite large patches, and again in little strings running through and through the feldspars, in the usual manner of secondary quartz. A number of these small patches of quartz lying near each other will polarize together, showing that they are part of one individual. Moreover, the same is true of the larger quartz areas, and numbers of small

---

*On *a priori* grounds, one might expect unindividualized magma to remain in sedimentary rocks when not completely changed.

†See detailed description, pp. 209-225.

particles lying near them, so that all of the quartz is considered to be secondary. This secondary quartz is frequently scattered through the feldspars in such a manner as to present the appearance of graphic granite, and again it is arranged in irregularly radiating lines. Chlorite is often present as an alteration product of both feldspars and hornblende. No base finer than the rest of the rock was observed, so that the name should apparently be syenite" (pp. 270-1).

Another variety of the "red rock" is described as true granitic porphyry. A rarer variety is a felsitic porphyry. These are all regarded as phases of the same rock.

In describing the Animike rocks in the vicinity of Thunder bay, lake Superior, he sums up by saying that they "consist of a great series, probably upwards of ten thousand feet in thickness, of quartzites which are often arenaceous, quartz-slates, argillaceous or clay slates, magnetic quartzites and sandstones, thin limestone beds, and beds of a cherty and jaspery material," (p. 379). He says also:

"Logan moreover, evidently took as Huronian, that part of the Animike group which 'occupies the coast for a distance of ten miles immediately below the mouth of the Kamanistiquia river, on the north side, leaning in a narrow strip, against the gneiss of the older series,'" (p. 379).

The Animike rocks are confidently identified with the rocks of the Penokee Range; but these latter, as has been stated, were with equal confidence identified with those of the iron-bearing series of Marquette. The Animike must therefore be the equivalent of the Marquette rocks. But Irving endeavored to trace some positive resemblances between the Animike and the rocks of Marquette; but without very convincing results, (pp. 385-6).

At this point the able author is seen to be on the brink of a broad fallacious inference. He takes up the consideration of the "Original Huronian," and correctly concludes:

"It appears to me very probable that the original Huronian of lake Huron and the Animike slates of Thunder bay, and thence southwestward to the Mississippi river, are one and the same formation," (p. 390).

This was the opinion first entertained by Logan;* but he subsequently associated those slates with the overlying Keweenawan. Then, as there was a lower, unconformable mass of slate conglomerates, he concluded to call those Huronian. Irving, however, while still holding to the Huronian character of the Animike, seems to have disregarded the vertical slate conglomerates, apparently because they graduate conformably into the crystalline schists and gneisses, and might be taken for a portion of that series —an unconformability between two systems supposed Huronian and Laurentian, having been noted at Penokee gap. Thus Irving held as Huronian what Logan held as a part of the Copper-bearing series; and Logan came to hold as Huronian what Irving took as part of the crystalline schist series. But when Logan based his description on what he now held to be Huronian and Irving overlooked, Irving thought them to apply to the iron series of Vermilion lake (as they readily did), and concluded that to be Huronian, though in truth the rocks graduated into the crystalline schists, while what he had rightly identified with Huronian on Thunder bay, was really an overlying and discordant series. But that discordance Irving had not yet discovered at any actual juxtaposition, and he devoted much effort to showing how two different formations of different dip and strike, might, at some former time, have approached each other with a common dip and strike, (pp. 392-4). In this state of the facts professor Irving feels himself in a dilemma when he reads Dr. Bell's descriptions of assumed Huronian rocks more remote from Thunder bay, and misunderstands Dr. Bell at the same time, as speaking of the rocks which *Irving* had correctly called Huronian. Nevertheless, Irving is able to convince himself that all the areas by anybody called Huronian, agree in such particulars as to justify him in sweeping them all into that category, (p. 395). Irving suspects indeed, that two groups of schists have been confounded by the Canadian geologists—"the iron-bearing schists of the Huronian and the schistose greenish phase of the older gneiss"—but he does not suspect that he has himself identified and confounded two other systems which, unlike these groups, stand in discordant mineralogical and structural relations to each other.

---

*Report of Progress, Geol. Surv. of Canada, 1844, p. 29.

1885. The overlap of professor Irving's Keweenawan studies on systems of older date, was the prelude to a formal investigation of the Huronian system as a specialty. This was undertaken also, under the auspices of the Government survey, and was in progress at the date of his lamented death. But some preliminary papers appeared, from which we may learn the fundamental positions which he was preparing to defend.* In the first memoir, the following areas of older rocks are grouped together under the designation Huronian:

---

*A first paper entitled "Preliminary Papers on an Investigation of the Archæan Formations of the Northwestern States." was published in the *Fifth Annual Report* of the U. S. Geol. Surv., 1885. pp. 175-242.

The Original Huronian.
The Marquette-Menominee Iron-bearing schists.
The Wisconsin Valley slates.
The Penokee-Gogebic Iron-bearing schists.
The St. Louis, [Minn.] slates.
The Chippewa Valley quartzites.
The Black River Iron-bearing schists.
The Baraboo quartzites.
The Sioux quartzites.
The Animike series.
Folded schists of Canada.

In the progress of a condensed examination of these eleven areas, professor Irving states more explicitly, what he intimated in his previous memoir, that the so-called "crowning overflow," resting on the Animike cliffs of Thunder bay and the regions to the southwest, is not to be regarded as one final overflow, but a succession of overflows, interbedded in a succession of slaty deposits.[*] He opposes sharply the position of Foster and Whitney, and later, of Wadsworth, that the iron deposits and associated jaspers are of eruptive origin (p. 192). The folded schists north and east of lake Superior, described by the Canadian geologists, since 1863, as Huronian, are admitted, at least some of them, in that system, but he says:

"We are immediately confronted with a structural problem of a good deal of difficulty, *i. e.*, the relation of these folded schists to the unfolded Animike series. Generally as the Animike series is traced toward its northern border, it is found to lie against a belt of granite and gneiss. This is so along the shore of Thunder bay, and thence westward to Gunflint lake, and it is true again at the Mesabi Range and Pokegama falls district, in Minnesota. North of this belt of granite, comes the belt of folded schists. The appearance thus presented is at first sight, one of general unconformity between the flat-lying Animike and an older series including gneiss and older folded schists."

This state of facts was in direct conflict with his theory that the Animike and the folded (vertical) schists are one. The reconciliation of the facts and the theory occupied his earnest attention. A hypothesis was proposed for this purpose.[†] He supposes "that the Animike rocks were once continuous with the folded schists to the north of them, and that they are now separated merely because of the erosion of the crowns of the folds between them, the close folding of the folded schists being supposed, on this view, to have been produced concomitantly with the broad simple bend which forms the trough of lake Superior. On this supposition, the unfolded schists of the north shore are compared with the unfolded Penokee of the south shore; and the folded schists of the national boundary, with the folded schists of the Marquette and Menominee regions. All are supposed to represent a great sheet of Huronian deposits once continuously spread upon a floor of far older gneisses and schists, which have since been brought to view by folding and denudation."*

---

[*] P. 203. See also, *Fifth Annual Report*, p. 382. The "crowning overflow" is now discredited by the present Director of the Canadian Survey—*Science*, ii, p. 675, 1884.

[†] *Third Annual Report, Wisconsin Geol. Surv.. p. 171; Monographs U. S. Geol. Surv.*, vol. v. pp. 399. 417; *Fifth Annual Report*, p. 206.

Some little support for this not impossible hypothesis, was gathered from the fact, that in one region, where the horizontal and vertical schists were separated by only a few miles, the horizontal schists acquired considerable dip. In some localities, as shown by N. H. Winchell, they became irregular in dip, and manifestly disturbed. But professor Irving was never able to proceed further.†

In the sequel of this memoir, the author presents other results of studies upon his general problem, and among them are interesting facts respecting enlargements of quartz fragments (pp. 229-230); and these lead him to an explanation of so-called "crystalline sandstones". (p. 219)‡ A final conclusion from these studies is "that all of the quartzites marked provisionally as Huronian on the accompanying map, including the type Huronian of lake Huron, are merely sandstones which have received various degrees of induration by the interstitial deposition of a silicious cement which has generally taken the form of enlargements of the original quartz fragments, less commonly, of minute, independently oriented areas, and still less commonly, of an amorphous or chalcedonic silica, two or even three forms of the cementing silica occurring at times together in the same rock" (p. 236).

---

* *Fifth Annual Report, U. S. Geol. Surv.*. pp. 206-207.

†The writer will here state that the Minnesota Survey has shown that the disturbances referred to (east of Ogishkemuncie lake) are very local, and the horizontal schists north of Gunflint lake are not separated from the vertical by a gneissic interposition, but rest in very discordant contact upon them. No more speculation is necessary.

Professor Irving read a paper before the *National Academy*, Apr. 22, 1887, which was published in *Amer. Jour. Sci.*, III, xxxiv, 204-216; 249-263; 363-374, entitled, "Have We a Huronian Group?" This was chiefly an occasion for restating the views presented in the paper here noticed, and for a final effort to elucidate his hypothesis for the synchronization of the Animike and the older schists now known as Kewatin. This paper has been noticed by me in *Bull. Geol. Soc. Amer.*, i. p. 387.

‡The subject has been more fully treated in *Bulletin U. S. Geol. Surv.*, No. 8, 1884, by R. D, Irving and C. R. VanHise.

Such enlargements in "Hornblendes and Augites" have subsequently been described by professor C. R. VanHise, *Amer. Jour. Sci.* III. xxxiii, 385-388, 1887.

The subject of enlargements of feldspar fragments is similarly discussed and the facts established.

A final conclusion from all the facts is that the most of the rocks generally styled Huronian do not properly fall under the head of metamorphic rocks.

These inferences are carried further in the important Bulletin cited above.

1888. The last important memoir from Professor Irving's pen is a compilation of fundamental principles to be employed in the classification of unfossiliferous rocks.*

Of this the author says: "Beyond many of the facts cited in illustration, and the mode of presentation, the paper does not contain very much that is new or original." It nevertheless presents a convenient synopsis of principles, and shows a mature mastery of the subject. For the present purpose a few quotations of new or maturing views on certain points, will suffice. Speaking of the green schists which with more or less of mica schists and other later rocks has been marked as Huronian for the entire region north of lake Superior by the Canadian survey, he says they are not separated from the Laurentian by any unconformity. Therefore, "The name Huronian belongs to an entirely different group."†

In attempting to illustrate the structural relation of the Animike series to the underlying schists, he presents (p. 421) a diagram section across Gunflint lake, which sets forth the observed facts with sufficient accuracy. But his interpretation of the fact seems to be erroneous. He says the Animike abuts "against an older formation of granite and schists," and he says too, "the iron-bearing horizon at the base of this succession [the Animike] is lithologically identical with that of the Penokee series of northern Wisconsin and Michigan." So far he is perhaps, right—but, with the understanding that the "granite" [gneiss] is quite removed from the *contact* with the Animike, and that the "schists" *at* the contact are not the usual crystalline schists which succeed the gneiss and granite, but hold a position superior to them, in the same vicinity. Professor Irving's misconception consisted in regarding those vertical "schists" as part of the series of crystalline schists, and in conceiving them as different from the vertical schists which inclose the iron ores at Vermilion lake. Identifying these vertically-standing ore beds with those in the flat-lying Animike, he makes

---

*"On the Classification of the Early Cambrian and Pre-Cambrian Formations. A brief Discussion of Principles, illustrated by examples drawn mainly from the Lake Superior Region." *Seventh Annual Report* U. S. Geol. Surv., 1888, pp. 363-454.

†Yet this is precisely the group which in the Vermilion region of Minnesota, professor Irving calls Huronian

an unsuccessful attempt to represent them as "flat-lying," like the Animike ores at Gunflint lake[*] (p. 421).

Professor Irving insisted on a "structural unconformity between the Huronian and Laurentian." He makes numerous references to Sir William Logan's utterances on the subject, and though they are strikingly self-contradictory, Irving asserts, they "show certainly his full belief in such unconformity" (p. 430). This confusion on Logan's part, and misapprehension on Irving's, arise from their common error in applying the name Huronian to two different systems, and Irving's supposition that the Penokee Huronian—rightly identified with the original Huronian—is the same as Logan's "Lake Superior Huronian."

In discussing the taxonomic exhibit which he gives of the older rocks (pp. 440-441) he says:

"At the base of the succession is a series composed of gneiss and granitic rocks, with also a large development of schists. The granite is certainly in the main eruptive. The schists are very largely compressed eruptives, but also in part of sedimentary origin" (p. 442). This view may be compared with those given, antė, p. 197.

But of the mica schists or mica slates described as holding a position near the top of the Marquette iron series, he says:

"Our own microscopical studies of them have demonstrated their derivation by mere metasomatic changes, from rocks wholly of detrital origin, the fragmental character frequently being well preserved, even to the naked eye, while large portions of the same horizon show little change from the original fragmental conditions." (p. 386.)[†]

As the outcome of the entire discussion, professor Irving presents the following taxonomic suggestion (p. 454):

Systems.	*Groups.*	*Systems.*
Paleozoic.	Carboniferous,	Paleozoic.
	Devonian,	
	Silurian,	
	Cambrian.	
Agnotozoic or Eparchæan.	Keweenawan,	
	Huronian,	
	(Other groups?)	
Archæan.	Laurentian (including upper Laurentian.)	Archæan.

---

[*] His diagram attempting this is in *Amer. Jour. Sci.*, III. xxxiv, p. 239.

[†] Such micaceous schists are what the writer, in the Fifteenth and Sixteenth Minnesota Reports, has styled "nascent mica schists."

Andrew C. Lawson.

1886. In his description and estimate of the rocks in the vicinity of the Lake of the Woods,[*] Dr. Lawson assumed positions of such originality and boldness as to entitle his contributions to an important place in this sketch of opinions concerning the older rocks of America.

The schists in the vicinity of the Lake of the Woods had been noticed by Bigsby and the other early explorers. By Bell, they had been designated Huronian, from their resemblance, undoubtedly, to the schists misnamed Huronian, on the north and east of lake Superior.[†] Dr. G. M. Dawson first remarked the apparent volcanic origin of a large part of the "Huronian" [‡]rocks.

Dr. Lawson is not satisfied to embrace all the older schists in the Huronian.[§] He says:

"The schistose belt of the Lake of the Woods appears to me to differ from the typical Huronian of Sir William Logan both lithologically and in other respects. The typical Huronian of Logan is, from his description of it, essentially a quartzite series, in which the quartzites are true indurated sandstones. The schistose belt of the Lake of the Woods is not so characterized. Quartzites form an extremely small proportion of the rocks of the Lake of the Woods, and then they are only local developments in formations of mica schist and felsite schist. Bedded limestones are characteristic of Logan's typical series. On the Lake of the Woods, there are, so far as I have been able to determine, no bedded limestones, the nearest approach to them being small segregated bands of dolomite of the character of veinstones. These two differences alone are sufficient to throw doubt on the equivalence of the two series, if lithological character is to be regarded as an aid to geological classification. There are, however, other differences. The basal conglomerate of Logan's Huronian, on Lake Temiscamang, is described as holding pebbles and boulders, sometimes a foot in diameter, of the subjacent gneiss, from which they appear to be derived. The boulders display red orthoclase feldspar, translucent colorless quartz, green hornblende and brownish black mica arranged in parallel layers, which have a direction according to the attitude in which the boulders were accidentally inclosed. The rocks on the Lake of the Woods, which are in the following pages referred to as agglomerate schists, are not basal conglomerates. They are not at the base of the series included in the schistose belt, nor are they apparently composed of water-worn fragments, derived from the rocks upon which they rest.

---

[*] Report on the geology of the Lake of the Woods region, with special reference to the Keewatin (Huronian?) belt of the Archean Rocks. By Andrew C. Lawson, M. A. *Geological and Natural History survey of Canada.* Annual report (new series), Vol. I, 1885, Montreal, 1886.

[†] R. Bell, *Ann. Rep. Canada*, 1872-3, pp. 91-105; 1873-4, pp. 88-89. Also, and more in detail, 1880-2, pp. 12-150.

[‡] G. M. Dawson, Geology and resources of the region in the vicinity of the forty-ninth parallel, 1875.

[§] The same dissent was expressed by the writer in a paper on "The Huronian System," presented to the *Amer. Assoc.*, New York, 1887; in one entitled, Systematic Results of a Field Study of the Archæan Rocks of the Northwest, *Proc. Amer. Assoc.*, Cleveland, 1888, p. 205-6; a paper on The Geological Position of the Ogishke Conglomerate, *Proc. Amer. Assoc.*, Toronto, 1889, pp. 234-5 and Two Systems confounded in the Huronian. *Amer. Geol.* iii, 212-14, March, 1889. See similar views embodied in a paper by N. H. and H. V. Winchell, *Proc. Amer. Assoc.* Toronto, 1889, pp. 235-242.

"No fragments that can be referred to the underlying granitoid gneisses are found included in the agglomerate schists of the Lake of the Woods. All the facts connected with them point to a volcanic origin for these agglomerates, and the fragments are very frequently sharply angular, often with re-entering angles, although for the most part, they are elongated and lenticular in shape, as a result of pressure, and the paste in which they are imbedded does not differ from them materially, as a rule. In rare instances, they pass into a pebble or boulder-conglomerate, in which the pebbles are usually of a reddish felsitic material, and indicate the coëxistence of aqueous with volcanic deposition."

"The 'green slate rock' conglomerates at the mouth of the Doré river, lake Superior, described by Sir W. Logan, supposed by him to be equivalent to the rocks of his main Huronian area, appear to resemble the agglomerate schists of the Lake of the Woods. This Doré river area of 'green slate rocks,' is however geographically distinct, and appears to differ from the series in the typical Huronian region. The rocks are described as standing in a nearly vertical attitude, while those of the latter are comparatively flat. Neither are they associated with beds of quartzites or limestones to a material extent. Those differences, with the geographical separation, may, I believe, warrant us in considering the possibility of Logan having placed under one designation, two distinct series."

Other and good reasons are given for the opinions here set forth, but we must forbear to cite further.

" While thus the schists of the Lake of the Woods are older than the epoch of folding, and older than the granites which are intruded through them, Logan's typical Huronian has come into existence later than the time of folding of the gneiss, and possibly also, later than the main period of granitic irruption."

He refers to Irving's conclusions as supporting his own view. Citing Irving's full identification of the Animike series of Thunder bay with the typical Huronian, and his view of the apparent equivalence of each with the Marquette, Menominee and Penokee-Gogebic series, he asks:

"If then, the Animike and Huronian are identical, as Logan himself believed, as regards a portion, at least, of the Animike, what are the relations of the folded schists of the Lake of the Woods to that flat-lying series? Professor Irving has expressed the opinion 'that both the flat-lying Animike slates and the more northern, folded, iron-bearing schists are Huronian,' and gives a diagram to show the hypothetical identity of the folded and unfolded series on either side of the Mesabi range of granite and gneiss" (See anté, p. 203).

"The folded schists to the northwest, however, so far as the Lake of the Woods series teaches, are as different from the Animike as they are from the typical Huronian, and were probably folded with the gneisses, before the Animike rocks existed as such. The Animike series rests, apparently, on granite, along part of its western confines. The granite of the region appears, as is known to have been the case on the Lake of the Woods, and has been more recently determined to be true also for Rainy lake, to be of later origin than the folded schists[*]. Hence, in the superposition of the Animike rocks upon the granite, we have, again, a sharp distinction in geological time, between the Animike (Huronian?) and the folded schists to the west, as represented by the Lake of the Woods series."

Dr. Lawson thinks, in this view of the facts, "it is expedient that this series of rocks should receive a convenient name which shall be non-committal as to geological relations, and which may be used provisionally, till such time as those relations are established beyond question. The most appropriate name for the series that suggests itself to me is *Keewatin* [*Ke-way-tin*], the Indian name for Northwest, or the Northwest wind, which has been applied to the district within which the rocks occur."[†]

---

[*] This view of the relative age of the granites and the schists has been more particularly argued by Dr. Lawson, in *Amer. Jour. Sci*, III, xxxiii, 473-480. Although the author speaks with confidence, the reader will not understand that the doctrine is established in the sense here conveyed.

[†] *Keewatin* as a Chippewayan term, has no authorized orthography. The sounds are represented in different European languages, according to the powers of the letters of those languages. It is doubtful whether the usage of the English language has a paramount right to impose a fixed form for universal acceptance on any Indian vocable, especially, when it is a term proposed for introduction into the universal language of geology. This diversity in the powers of letters in different languages, led Americanists long since, to the adoption of certain rules for the spelling of Indian names. The alphabet of Dr. George Gibbs, the recognized pioneer in American linguistics, was adopted by the Smithsonian Institution, and published with its sanction, in No. 160 of Smithsonian Miscellaneous Collections, 1866. The rules thus pro-

Coming to a geological description of the region, the author dwells upon the existence of great pre-glacial denudation; but in a later memoir, this subject is treated more at length.

To the gneissic and granitic rocks he ascribes an origin from molten material. He states that the non-orthoclastic constituents of the gneiss possess "a distinct flowed structure." The gneisses, he says, too, show a "passage into granites devoid of foliation" (p. 29). Of one of the granites he says:

"This rock, characteristically granitic in its nature, may be traced eastward over a comparatively bare country, and be seen to assume gradually, by transitions scarcely perceptible, a gneissic arrangement of the crystals, till at last, on the shores of Long lake, it presents a quite distinctly gneissic foliation" (p. 30).

A group of rocks of great importance but very obscure nature, is described as "agglomerates, tuffs and boulder conglomerates." The character which they present he considers due to "an extremely rapid process of deposition of intimately associated and often alternating, volcanic ejectamenta, (both flows and tuffs) and aqueous sedimentation, the material for which was derived partly from the volcanic products, and partly from the more silicious or acidic rocks which seem to have constituted the original floor of the trough" (p. 49).*

Further of the constitution of the agglomerates, he says:

"The included fragments of the agglomerates are nearly always more or less flattened or lens-shape, the greatest planes in the fragments being parallel with the planes of schistosity, which are in the great majority of cases observably identical with those of the bedding" (pp. 49-50).

The forms of the fragments are attributed to pressure. The agglomerates are said to pass, sometimes, into mica schists; and he says it is "not uncommon to find in these mica schists, a small proportion of feldspar, which gives them the character of finely laminated gneisses, in places."

---

mulgated have been followed in the various publications of vocabularies made by the U. S. Department of Ethnology. (See, for instance, Contributions to North American Ethnology, vol. i. p. 243, 1877, and iii, p. 443, 1877). Under these rules, the vocable *Ke-way-tin* should be written *Ki-wi-tin*; as the vocable *Ke-we-naw* would be written *Ki-wi-na*. But should it be considered too late to adopt the Smithsonian orthography of these words, there certainly is no English reason for inserting duplicated "*e*", as in *Keewatin* and *Keweenaw* (why not *Keeweenaw?*). The least concession to the demands of simplicity and good orthographic reason, should prompt a user of the English language to write *Kewatin* and *Kewenaw*. For similar reasons, we should write *Animike*. not *Animikie* or *Animikí*; *Ke-ke-qua-bic*, not *Ka-ka-quà-bic*. Also, *Couchiching*, not *Coutchiching*.

*A similar view of the nature of the "diabasic schists" of Minnesota has been set forth by H. V. Winchell, in the *American Geologist*, iii, pp. 18-22. Jan. 1889.

Thus, since the gneiss graduates into granite, he discovers a mineralogical graduation between mica schist and granite.*

Particular attention is devoted to the relations of the gneisses with the associated schists. "The gneiss", he says, "in some places, holds large and small angular fragments of hornblende schist . . The planes of *lamination* of the schist and *foliation* of the gneiss are parallel, though there are *unmistakable* evidences that the contact is an igneous one, and that when there is a mixed alternation of gneiss and schist, the former has been *injected* within the latter [italics are the compiler's]. This mixture of gneiss and schist, with occasional short broken bands and fragments of schist included within the gneiss, occur at intervals along the shore of Darlington bay" (p. 64).

In another place, he speaks of "dykes and gneiss" cutting the schists, and presenting the appearance of "evenly intercalated beds" (p. 72). As we approach the great gneissic area, these intercalations become more frequent. At the junction between the gneiss and schists, there is "no sharply defined line of contact, but a transitional series of layers of alternate gneiss and schist" (p. 72).

He gives figures of such alternations, and says:

"The two rocks [are] apparently interbedded as a transitional alternation, but the gneiss [is] in reality intruded." In one place he enumerates sixteen alternations of gneiss and hornblende schist, "some of the gneissic beds being as thin as four inches, six inches, eight inches and one foot, with intervening schistic beds as low as eight, twelve and fifteen inches, all regular and bed-like in their characters;" "but their true nature," he says, "as injected sheets or dykes, is sufficiently revealed." This opinion seems to be rested on the facts that occasionally a bed of gneiss sends "irregular tongues" into the schists, or includes "fragments of the schist walls."†

The plutonic view is defended by the author with unmistakable ability, (p. 83, etc); but we have not the space for adequate citations. The Kewatin is held, with reserve, to be structurally conformable with the Laurentian; but at the same time, it is presumable that a real historic break separates them.

---

*Nevertheless, so far as the writer can ascertain, he regards the Kewatin as embracing all the rocks down to the gneiss, where, for the reasons given, he discovers evidences of a very different sort of geologic agency.

†Similar relations of gneiss and contiguous schists are described in the *Fifteenth* and *Sixteenth Annual Reports* of Minnesota; but a different interpretation is put upon the gneissic beds. See also the writer's memoir in *Bull. Geog. Soc. Amer.*, pp. 357-394. Apr., 1890.

As to the general structure of the region, he says:

"The granitic intrusions of the area of the Lake of the Woods may be grouped under ten main centres of occurrence or distribution, with a number of bosses of minor importance, which appear to be independent of these."

These areas are regarded as so many outbursts through the overlying Kewatin and are therefore of later age. The granitic masses have a definite relation to the stratigraphical structure, and seem to lie in the lines of folding, and to have been affected by the same cause as produced the folding (pp. 100, 101).

Of the Kewatin series he enumerates and describes the following members:

"Granitoid rocks at either extreme.

"Hornblende schists with associated altered traps, the whole more or less chloritic.

"Agglomerate schists, varying in character from greenstones to micaceous or gneissic schists.

"Quartzose mica schist, sometimes gneissic, but lamination ver y even.

"Hydromicaceous and chloritic schists, and arenaceous slates.

"Granite (irruptive)."

1887. In continuation of the results of his studies in the Canadian Northwest, Dr. Lawson gave a preliminary account of the geology of the Rainy lake region.* This region geologically is a continuation of that of the Lake of the Woods. He here brings out more expressly his belief that the granitic and gneissic rocks are younger in respect to the conditions in which we know them, than are the crystalline and semi-crystalline schists. He says truly:

"We do not yet know their original condition prior to the fusion from which they solidified into granites, syenites and gneisses. They may have been sedimentary; they may have been the original crust of the earth. But whatever may have been that original condition, the evidence is clear on this point, viz: that the fusion and solidification whereby they were brought into their present condition as firm crystalline rocks, took place at a period subsequent to the existence, in a hard, brittle condition, of the stratiform, and often very distinctly clastic, rocks which occupy the higher place in the column. Therefore, as rocks, the members of this fundamental system are of younger age than those of the nearest overlying formations."

But he draws the line of distinction between igneous and sedi-

---

***Amer. Jour. Sci.*, III, xxxiii, 473-480, June, 1887.

mentary rocks at the crystalline schists. He includes here certain fine-grained, bedded rocks for which he proposes the term "*granulite gneiss.*"[*] The schists generally known as crystalline schists, occupying a position between the gneisses and the semi-crystalline schists, are here separated from the latter, and receive the name, "Coutchiching series."[†]

He says of them:

"They are very sharply and distinctly marked off from the lower granites and gneisses of the Laurentian. The geological contact between the Coutchiching series and the Laurentian is one of neither conformity nor unconformity. The break is of an entirely different order, and the contact is eminently that of an igneous injection or intrusion of the lower through the upper rocks" (p. 477),

The overlying [Kewatin] schists are "of entirely different character." The rocks are for the greater part "of volcanic origin' Though structurally conformable with the Couchiching series, the appearance of parallelism may be the result of folding and pressure. The diverse character of the rocks of the two series is proof of a profound alteration in the conditions of rock formation, which implies a geological break.

Regarding the systems in order of superposition, he arranges them thus:

Kewenawan (Nipigon).
Huronian (Animike).
Kewatin.
Couchiching.
Laurentian.

But regarding them in the order of age, they would stand thus:

Kewenawan (Nipigon).
Huronian (Animike).
  Diabase dykes and gabbro,
  Granite, post-Laurentian.
Laurentian.
Kewatin.
Couchiching

1888. Dr. Lawson's final report on the geology of Rainy lake region appeared in 1888.[‡] This thoroughly scientific memoir, in the discussion of doctrines, is devoted rather to the strengthening of positions previously assumed than to the elimination of new views, and thus, in spite of its value, does not seem to demand more than the citation of a few passages. Among the facts however, which possess greatest interest, are some occurrences of a conglomerate which, as nearly as may be judged, is an extension of the Ogishke conglomerate of Minnesota.

---

[*] This convenient and appropriate term has been used many years by the present writer. This, as also "granulite schist," are given in his "Geological Studies," pp 51 74, 76, etc. 1886.

[†] Better *Couchiching*, for reasons stated above.

[‡] *Geological and Natural History Survey of Canada.* Annual Report (New Series), vol iii, Part I, pp. 182, with a map.

"On the shores of Rat-Root bay, the basal beds of the Keewatin are pebble-conglomerates, of which the paste is a green schist, and the pebbles mostly water-worn, rounded or oval pieces of vitreous or saccharoidal quartz. Some of the pebbles are feldspathic, and when so, are occasionally foliated. On the south shore of the bay, boulders of granite are observed to form part of the conglomerate, one boulder being at least eighteen inches in diameter, and of a roughly rounded shape" (pp. 38, 82, 105).

Again on Grassy lake, the basal beds of the Kewatin "are fissile, soft, green-chloritic and hornblendic schists, the detrital origin of which is established by the fact that on the north side of the lake, they constitute the paste of a pebble-and-boulder-conglomerate" (pp. 55, 82). This conglomerate is much more voluminous on the north side of Shoal lake.

Among the soft fissile, glossy gray schists of the Kewatin series at the west end of Schist lake, there are several beds of conglomerate, the pebbles of which are mostly quartz rock, and the matrix a soft, more or less calcareous, decomposed schist, stained yellowish with oxide of iron.

He notes the parallelism of the two series and says again, this affords but little evidence of original conformity; and relies upon the abrupt lithological contrast for evidence of a historical break. The conglomerate he regards as a *basal** conglomerate "in which the pebbles have very probably been derived from the underlying formation" (pp. 56, 105).

He notes, what has also been observed in Minnesota, that the series of crystalline schists is quite inconstant in its occurrence. Sometimes the Kewatin rests on the gneiss, and then the basal member is likely to be hornblende schist. But this schist is apt to be wanting when the Kewatin rests on mica schist (p. 38).

Of the hornblende schists he says:

"There is much presumptive evidence in favor of the view that they are partly altered, massive rocks, and partly altered, volcanic ash-beds (pyroclastic), but little or none, that they are the alteration products of clays or other forms of detrital matter."

---

*This position of the Ogishke Conglomerate of Minnesota has seemed to the writer clearly pointed out by the facts observed. See *Sixteenth Ann. Rep.* Minn. pp. 344-350; 359-360.

The changes undergone have been so profound that the original character has been destroyed, and a new rock of different constituent minerals has crystallized *in situ*. Pressure and crushing may have been potent in the destruction of the original structure; but in the later history, chemical or metamorphic forces have been chiefly active, and have obliterated all the traces of crushing (p. 73).

Of the soft, fissile, green schists he says:

"These are schists closely resembling the paste of some of the conglomerates. They are usually distinctly bedded. Their clastic origin can scarcely be doubted, though, as in the paste of some of the conglomerates, their association with bedded traps and their mineralogical analogy with the altered phases of those traps, renders it extremely probable they were never ordinary clays, but were originally fine-grained, volcanic ash-beds, the constituent minerals of which have suffered alteration and decomposition along the same lines as those observable in the traps" (p. 82).

He finds few serpentines. Their relations to the rocks adjoining them are ill-defined. They appear to be the alteration products of igneous masses which have the same geological age as the traps and other volcanic rocks of the Kewatin series; and although their common boss-like character suggests that they are intrusive through the Kewatin rocks, such intrusion has probably taken place coëval with the bedded formations, volcanic and sedimentary, of the Kewatin (p. 97).

In reference to the relations of the Couchiching series to the Kewatin and Laurentian, he remarks:

"Without being able to conclusively prove it, there appears to be much presumptive evidence in the facts cited, to show that the present eminently crystalline state of the Coutchiching series is the result of the metamorphism of strata which were originally in large part, ordinary quartzose sediment, although part may possibly have been acid volcanic rocks, such as quartz-porphyries or felsites. In many parts of the series garnets abound, and if the rocks were carefully examined, other metamorphic minerals would doubtless be found. That percolating silicious solutions were active agencies in effecting the metamorphism of these strata, is proved by the fact that in many places, particularly on the north side of Saginaw bay and east of Brulé narrows, the partings between the beds have served as fissures for the deposition of vein-quartz. This vein-quartz is very abundant in lenses or lens-like sheets, and is clearly a secondary product in the rock. The same watery solutions which desposited the quartz in these lenses, n the more open portions of the formation, must have saturated the rock throughout, and given rise, probably, to much of the quartz and feldspar in it. Only in one instance has hornblende been observed throughout the whole series. There are no intercalations of basic volcanic rocks, and none that can now be distinctly recognized as acid volcanic rocks. There are no limestones or dolomites in the series, nor have any conglomerates been observed." (p. 105.)

The subject of inclusions in the Laurentian gneiss is very particularly treated. These gneisses, both of the granite and the syenite type, frequently consitute a matrix in which angular fragments of schists are inclosed. These are most abundant in the vicinity of the lines of junction with the overlying schists. The included fragments may belong either to the Couchiching or Kewatin series. Along the zone of contact, apophyses or dykes from the gneiss penetrate the contiguous sheets. These facts are thought to prove that the inclusions are simply detached portions of the overlying formations "which in a firm and brittle condition, have become immersed in the underlying viscid magma, which subsequently crystallized out as the Laurentian gneiss and granite. It seems probable, too, that such shattering and detachment of fragments took place at the last stages of crumpling of the crust in this region. . . After the solidification of the Laurentian gneisses, there was no farther very violent deformation of the crust, for the Laurentian rocks appear to have resulted from the fusion not simply of the floor upon which the Coutchiching and Kewatin rock first rested—what ever such floor may have been[*]—but also with it of portions of those series" (pp. 130, 131).[†]

1890. Early this year, Dr. Lawson published a thoughtful and important memoir on the internal relations and taxonomy of the Archæan of Canada.[‡] He discusses, first, the separability of the Archæan into two divisions, which, with subdivisions, would present the following scheme:

---

[*] The recognition of the necessity of a "floor" on which the marine sediments could have rested, is a tacit admission of the existence of a geological formation older than that formed from the sediments. To say that we know nothing of that solid floor except as an inference, is the same as we must say about the former fused or plastic condition of the granites and gneisses. The indications of such plasticity afford no stronger basis for the inference than the indisputable necessity of a solid non-igneous sea-bottom to support the waters of a sediment-laden ocean. We have, in reason, in both cases, satisfactory ground for a conclusion, and in both cases, proof from observation is precluded. In fact, the conclusion that molten masses of granite emerged through or into beds of strata already existing, possesses the same kind of support as the conclusion that a solid foundation earlier existed for the penetrated strata to accumulate upon. It is, in short, demonstrable that the schists have no claim to be reckoned first in the order of time.

[†] Phenomena of the class here described have also been fully detailed, with many illustrations, from the contigous territory of northern Minnesota. See *Fifteenth* and *Sixteenth Annual Reports, Geol. Surv. Minn.*, 1886, 1887.

[‡] *Bulletin of the Geological Society of America*. pp. 175-194. March 20.

ARCHÆAN.
  Ontarian. [Now first proposed.]
    Kewenian.* [Nipigon.]
    Huronian. [Animike.]
    Kewatin.* [Often confounded with Huronian]
    Couchiching.* [Vermilion of N. H. Winchell.]
  Laurentian.

In presenting a petrographical description of the members of the Ontarian division he says of the hornblende schists:

"The field evidence points to their derivation from basic volcanic rocks," and cites examples from Norway and Scotland tending to prove "the derivation of the bulk of the hornblende schists from normal volcanic massive rocks, which were originally bedded with other stratified rocks, either as flows or as injected sills. Other hornblende schists are probably derived from an analogous alteration of tuffs of basic volcanic rocks" (p. 179).

As to the extent of the influence of metamorphism in the Ontarian system, Dr. Lawson offers reflections which narrow the gap between him and the metamorphic school. He says:

"In deference to these [plutonists] and other anti-metamorphic schools of thought, in which for the most part, theory seems to crowd out fact, it becomes necessary, with the accumulation of evidence of recent years, to point out the great additional strength acquired by the theory of metamorphism as applied to the Archæan by the recognition of the volcanic origin of much of the material upon which metamorphic agencies have operated, and by the limitation of its application to the upper division [Ontarian] of the Archæan; the rocks of the lower division, or Laurentian, being susceptible of an entirely different explanation. The lack of discrimination between the essentially different characters of the upper and lower Archæan, and the lumping of the whole complex together as having necessarily the same origin and development has been the great mistake alike of the metamorphic and the extreme plutonic schools. Just as the metamorphic theory, properly limited, affords the explanation of the development of the rocks of the upper Archæan from normal formations, so by a similar limitation of the plutonic theory, and the introduction of some modifying considerations, we will find in the latter, a rational and consistent explanation of the origin of the rocks of the Laurentian" (p. 181).

---

*Kewenian is not named in this connection, but in previous documents it is put in the position here indicated.

Although this slightly simplified orthography of three of these divisions is here used by the writer, the terms are considered the same as those employed by Dr. Lawson.

In writing of the Couchiching series, for which the name "Vermilion series" was employed by N. H. Winchell about the same time as proposed by Dr. Lawson, he takes occasion to express regrets that the present writer had used "Vermilion series" and "Vermilion system" "in a much more comprehensive, but still undefined sense." It is proper to say that those expressions were not intended as taxonomic in value, but simply as geographical, referring to the whole assemblage of rocks about Vermilion lake.

In another memoir, Dr. Lawson has recorded* important observations on the pre-Palæozoic surface of the Archæan terranes of Canada. The surface known as *roches moutonnées*, generally attributed to the action exerted during the last glaciation, is seen to have existed when the Palæozoic sediments were laid down—formations of whatever age adapting their under surfaces to the bossy surface of the Archæan.

Another announcement possesses similar interest. Vestiges of Palæozoic strata are now known in so many districts resting in the protected depressions of the Archæan, that it appears probable that a large part of the Archæan surface was once covered by a blanket of fossiliferous rocks. In this view, the region which we call the Archæan nucleus of the continent was not visibly such until after a vast amount of denudation; though of course, it really existed as a grand swell in the fundamental structure of North America. A further inference from such a fact is the certainty that the material of the Palæozoic sediments was derived from some source now lost to view.

It becomes necessary to bring to a close our citations from the views of American workers on the nature and history of the older rocks. Though the undertaking has produced more voluminous results than were anticipated, there still remains a large body of valuable opinions, to which justice demands, probably, that some reference be made—opinions both of those who have been quoted, and opinions of others who, thus far, have been but incidentally mentioned. Regretting the necessity for these omissions, the compiler hopes, nevertheless, that what has been presented, may prove useful to many students in this difficult field of inquiry.

ERRATA.

Page 77—For "Bucoides" read Fucoides.
Page 83—For "It is intended" read It is not intended.
Page 108—After "Georgia trilobites" insert to.
Page 113—Dele "[4]" and five lines below substitute [4] for [5].
Page 126—Last line for x read plus.
Page 207—For "recents the following" read presents the following.

---

* *Bull. Geol. Soc. Amer.* 163-174, March 12, 1890.

INDEX.

- Adams, C. B., on red sandrock...... 98
- Addison Vt., fault at.................. 71
- Adirondacs named..................... 70
- Agamok lake.......................... 187
- Agate bay.............................. 200
- Agglomerates........................209, 211, 213
- Agnotozoic of Irving... 207
- Albany granite......................... 165
- Algonkian.......... ....119 note
- Algonquin terrane............ .....119 note
- American opinion on the older rocks 65
  - method of treatment of......... 66
  - history of useful................ 66
- Amygdaloids, Hugohton on.......... 89
- Animike formation........113, 145 note, 155
  - not Huronian..................... 155
  - recognized as Huronian.......... 156
  - first recognized in Minnesota.176, 183
  - distinct from Kewatin.......... 186
  - excluded from Keweenawan... 200
  - equivalent of..................... 201-3
  - parallelized with Kewatin....204, 306
- Anorthosite..................... .....126, 129
- Anse l', argillites at.................. 156
  - Rominger on............... 193
- Anthracitic particles.................. 136
- Apostle islands......................... 195
- Appalachian inversions 94, 95
  - W. B. Rogers on 101
  - H. D. Rogers on.................. 106
- Arenaceous slate group.............190, 192
- Argenteuil 125
- Argillytes at Lake Superior.......... 172
- *Arthrophycus, harlani*................ 98
- Arvonian................. 155
- Atlantic system........................ 166
- *Atops, punctatus*..................... 81
  - *trilineatus* ... .77, 107
  - redescribed by Hall............. 78
- Augen gneiss 164, 167
- Augusta county, Va., geology of..... 79
- Axis, geological, in Vt., and N. H. . 169
- Azoic system, method of.............. 66
  - proposed in America by Foster and Whitney.................. .. 143-5
  - remarks on....................... 144
  - equivalent to Taconic.......... 144
  - distribution of.................... 146
  - defended 148-9
- Bad river................................ 198
- Bailey, L. W., cited............. 157
- Bald mountain...... 79
- Baraboo quartzyte..................... 195
- Barrande, at variance with Hall....80, 108
  - defends Taconic................. 81
  - response of, to Logan...........82, 126
  - on Georgia slates.. ....99, 100
  - principles of in Bohemia........ 110
- *Barrandia, thompsoni* 108
  - *vermontana* 108
- Bastard 129
- Batchewahnung bay 134
- *Bathynotus holopyga*...................79, 108
- Beche, de la, quoted 145
- Bell, R., quoted....................... 208
- Berkshire county... ....68, 74, 80
  - limestone in..................... 92
  - inversions in... 102
- Bete grise bay......................... 200
- Bigsby, Dr., on labradorite.......... 125
- Billings on Taconic 81
  - on Quebec group.. 138
- Biographic method here pursued.... 67
- Birdseye limestone.................... 72
- Bischof on hornblende rock.. 159
- Black slate at Montmorenci 71
  - in Taconic.....................77, 78, 79
  - Hitchcock on.................... 99
- Blue Ridge............................. 104
- Blythfield....................... 127
- Bohemia, Barrande on................ 110
- Bonaventure formation....... ...157 note
- Boulders for building purposes...... 88
- Brooks, T. B., cited 155
  - opinions of.....................169 seq.
  - table of groups of 170
  - their sedimentary origin..... 170
  - on diorite rocks................ 171
  - on magnesian schists 172
  - on quartzyte 172
  - on argillytes 172
  - on same in Huron Bay district. 172
  - on carbonaceous slates 173
  - on Menominee iron range 173
  - on Wisconsin geology........... 173
  - on equivalences between Menominee and Marquette rocks.... 173
  - on comparison of regions....... 174
- Brown sandstone of Taconic......... 77
- Burlington (Vt.) sandstone........... 109
- Burt, W. A., cited..................... 91
- Calciferous sandrock 72
- *Calymene beckii*.....................78, 107
- Cambrian system, Emmons on....... 72
  - Hunt on 154
  - in New Hampshire 167
- Carbonaceous slates 172-3
- Carp river............................... 193
- Chamberlin and Irving.............. 91
- Champlain division newer than Taconic.................................. 77
- Chateau Richer 125
- Chenaux islands 128
- Chequamegon bay 198
- Chert beds at Thunder bay 136
- Chilhowee sandstone................. 104
- Chloritic slates 112, 113
- Clarendon.... 128
- Cleavage planes....................... 158
- Commonwealth mine 193
- Conglomerate, Houghton on.......... 90
  - Whitney on................ .141, 142-3
  - von Buch on................. .. 141
  - (See slate conglomerate.)
- Conglomerates in gneiss..97, 118, 128, 129
  - in crystalline horizons 185-6
- Contact of Huronian and Laurentian 122, 124, 130, note, 135
  - Hunt on ... .151, 152, 154
  - Irving on 207
  - Lawson on.... ....212, 214
- Contact unconformable............... 135
- Copper-bearing rocks of L. Huron. 119, 124, 135, 155
  - of L. Superior.........126, 135, 138, 203
  - lower group of "upper" described 136
  - age of, according to Whitney.. 140
  - made a distinct system......... 195
  - (See Keweenawan.)
- Copper lands, Whitney on..... 141
- Copper, veins of, Whitney on........ 143
- Coutchiching series.................214, 216
- Credner, H., cited...................... 155
- Crowning overflow 137, 204
- Cupriferous series 137
  - Whitney on 142, 147-8
  - (See copper-bearing rocks.)

Dana, J. D., quoted. 70
  error of, in date................. 71
  phase I. of...................... 75
  phase II. of 77
  equivalences of Taconic announced by 78
  phase III. of....................... 78
  equivalences..................... 82
  on Quebec group 138
Dana, S. L., opposes Taconic........ 77
Dawson, G. M., on Lake of the Woods 208
Dawson, J. W., on New Brunswick.. 156
Desor, E., proposals by............... 119
Dewey, Dr. C. and Emmons.......... 67, 77
  on Berkshire county 68, 92
Dikes in Upper Peninsula............ 89
  on L. Superior.................... 201
Dimetian series 155
Dioritic group...............155, 156, 190, 191
Dioritic rocks.......................... 171
Dips and strikes, in Vt................ 158
  in N. H 160
Dips anomalous in western Vt....... 72, 75
  Hitchcock on 92
Dolomytes, origin of, Hitchcock on. 96
  change of view on.............. 99
  at Thunder bay.................... 136
  C. H. Hitchcock on.............. 159
  in Minnesota.................. .. ·179
Doré river.......................133, 134, 209
Duluth 175, 183, 201
Elliptocephalus asaphoides.........77, 81, 107
  redescribed by Hall, and relocated 78
Ells, R. W., cited........................ 157
Emmons, Ebenezer opinion of....... 68
  on Berkshire county 68
  on second district of New York 69
  on Falls of Montmorenci....... 71
  plan of............... 74
  revision of Taconic by.......... 75, 76
  volume by, on Taconic 76
  agric. rep. by..................... 76
  in jour. of agric................. 77
  manual of geology by 80
  opinions in same 81
  removal of to N. C.............. 81
  correspondence of with Marcou 82
  on red sandrock of Vt 98
  on Potsdam sandstone... 126
Eolian limestone.. 99
Eozoic system.........................164, 165
Eozoon, Whitney on.................148, 149
  Hunt on........ 150
Eparchæan of Irving 207
Essex county, Emmons on 69, 70
Falls of Montmorenci, Emmons on.. 71
False steps inevitable 67
  to be pardoned 67
Fault from St. Lawrence into Vt. and N. Y.......................... 71
Felch mountain................ 156
Field stones for building purposes.. 88
Foliation due to sedimentation 158
Fossils absent from Taconic 76
  present in it......... 77
Foster and Whitney............. 91
Fox lake 187
Fucoides in Taconic 77
Gabbro in Mt. Washington....... ... 166
  in Minnesota 184
  at Lake Superior................ 201
Gabimichigama lake.. 186
Garnets in gneiss 127
Geographical method of Whitney and Wadsworth 67
Geology of New York........... 106
  Pennsylvania 105
  Vermont 80, 96, 98
  Minnesota 80
  Wisconsin 110
Georgia, Vermont...................79, 80, 81
  Hitchcock on.......................99, 100
Gneiss, of Emmons...................... 69
  views on by Hitchcock...... 93, 98, 99
  by C. H. Hitchcock.............. 158
  by Irving 197
  by Lawson.......................211, 212
Gneisses of Pennsylvania............105, 106
  of Vermont................... 158, 159
  interstratified with schists ...158, 212
  of Michigan........................ 190
  age of relative to granite....... ....213, 214, 217, note
  inclusions in.................... 217
Giant's range 184
Gibbs, G., on orthography of Indian names 210-1
Gogebic iron ores.. 156
Goulais river 134
Grand Marais... 178
Grand Portage..........................175, 176
Grandes Sables.......... 131
Granite, metamorphic origin of.99, 100, 197
  eruptive origin of................ 190
Granite (so-called) of Essex county. 69
  considered eruptive by Emmons.............................. . 74
Granitic group of Rominger.......... 190
Granular limestone..................... 99
Granular quartz of Taconic.73, 75. 76, 77, 78, 79, 83
  Hitchcock on 99
Graphite not evidence of organization 149
Graptolites in Taconic................ 79
Grassy Lake............................. 215
Graylock 75
Gray sandrock of L. Sup., 90, and note 91
Graywacke in Massachusetts 92
Great Lake George..................... 88
Green mountains 97, 100, 151, 158
Greenstone, transition of to granite 89
Grenville series........................154, 155
Gros cap..................... 133
Gull lake 179
Gunflint lake....177, 178, 180, 186, 204, 205, 206
Haldeman, S. S., on Taconic trilobites ....78, note
Hall, James quoted..................... 70
  describes *Atops, etc*.... ....78, 107
  describes other trilobites.......79, 107
  at variance with Barrande..... ·80
  on Georgia Vt. slates 100
  views on older rocks............ 106
  opposes Taconic................. 107
  reasons for assigning his trilobites...................... ..107, 108
  abandons Hudson R. group.... 110
  on Quebec group................ 138
Hastings series... ....151, 152
Hawes on Labradorite rocks........ 166
Higgins and Hubbard 91
Highlands of Hudson and of Quebec 72
Hitchcock, C. H., on Champlain.119, note
  opinions of ....157 *seq*
  on azoic rocks................... 157
  on foliation. 158
  on metamorphism............... 159
  on sedimentation in the White mountains 165
  on porphyritic gneiss..........166, 167
  on structure of New Hampshire 166
  on geognostic history of... 166
Hitchcock, E., appears to oppose Taconic........................... 70, 77
  views of, on older rocks......... 92
  rejects hypothesis of overturn. 92
  commendation of Emmons, by. 93
  theorizes on mica slate......... 93
  and on serpentines.............. 93
  and on gneiss........ 93
  and on granite................... 94
  elementary geology, by........ 94
  accepts theory of overturn..... 94, 95
  views of, not identical with those of Rogers................ 95
  on metamorphism........95, 96, 99, 100
  on dolomites...... 96
  on red sandrock of Vt.......... 98

  on Taconic system 100, 101
  on position of Georgia trilobites 108
  opinion of, modified 108
  on interpretation of fossils 100
  yields somewhat to Emmons' claims 111
  these views partly retracted 111
Hoosic mountain 73. 75
  Hitchcock on 92
  Rogers on 101–104
Hornblende rock 150
  schist 215
Houghton, D., views of on older rocks 87
  on Lake Superior sandstone 142
  associated with Schoolcraft 87
  labors of 91
  cited by Logan 115
  on conglomerates 143
Hubbard and Ives 91
Hudson river rocks, Emmons on 72. 75
  Hall and Logan on 107
  Hall on 110, 111
Hunt, T. S., on azoic rocks, method of 62
  criticisms on 67
  on Stockbridge limestone 99
  on crystalline limestones 125
  on Quebec group 138
  opinions of 150 *seq.*
  relations of to Canadian survey 150
  first to use "Huronian" 150
  on indications of organic life 150, 151
  on Terranovan series 152
  on Taconian 153
  on classification of Archæan 153, 154
  change of view of 166
  on Marquette diorytes 171
Huntington on porphyritic gneiss 168
Huron lake, geology of 114
Huronian first employed 121, 124
Huronian quartzyte 88
Huronian rocks described 122, 130
  traced to lake Superior 124
  base of 130
  section of 131
  of lake Superior 131, 132
  described by Logan 132–4
  correctly identified at L Sup. 137
  studied by N. H. Winchell 186
  Irving on 197
  reputed Huronian not true Huronian 199
  specially studied by Irving 203
  Lawson on 208
  a double system 208
Hypersthene rock of Emmons 70
  Logan on 120
Ile Royale 195
Inclusions in Laurentian gneiss 217
Inverted flexures 102
Inversion of Appalachian strata 94. 95
Iron-bearing series of lake Superior 135
  Whitney on 143
  taxonomy of 143
  called Huronian 155
Iron group of Rominger 190
Iron ore in Essex county 70
Iron ores supposed igneous 146
position of 156
  not igneous 204
Iron oxides not evidence of organization 149
Irving, R. D., opinions of 195 *seq.*
  on Baraboo quartzyte 195
  on Wisconsin Laurentian 196
  on absence of eruptive granite 196, 197
  on gneiss 197
  on derivative hornblende 199
  on volcanic pebbles 200
  on the red rocks 201
  on secondary enlargements of minerals 201-2
  on equivalences of Huronian 203
  special study of Huronian by 203
  on origin of iron ores 204
  attempt of to synchronize Animike and Kewatin 204
  on principles of geological classification 206
  taxonomy of 207
Jackson, C. T., on lake Superior 140
Jasper beds 136
Jaspilyte 187
Jewett, E., favors Taconic 81
Johnson's mountain, fault at 71
Kaministiquia river 114, 134, 135, 136
Kewatin, parallels of 187
  supposed parallels 206
  as a term 210
  recognized on lake Superior 113, 132, 134
  constituents of 213
Keweenaw point 146, 195
Keweenawan system 91, 137, 198
  Hunt on 154
  Brooks on 173
  founded by Irving 198
  as a term 199 note
  memoir on 200 *seq*
Kimball, J. P., cited 155
Knife falls 180
Knife lake slate 177, 178
Knox group, Tenn 104
Labrador feldspar in Essex county 70
Labradorian 127, 151
Labradorite 164
Labradorite rocks 165
Lake Hanbury slate group 194
Lake of the Woods 208
Lake Superior sandstone 88
  distinct from a lower one 90
  various views on 90, note, 140
  Jackson's views on 140
Laurentian first announced 119, 124
  previous use of the term 119, note
Laurentian system, subdivided 124. 127
  described 126-9
Lawson, A. C., opinions of 208 *seq*
  on Huronian 208
  Kewatin proposed by 210
  on interbedded gneisses and schists 212
  on Coutchiching series 214
  on relative age of granite and crystaline schists 214
  on hornblende schists 215
  on fissile green schists 216
  on serpentines 216
  on inclusions in gniess 217
  on the Archæan of Canada 217
  on metamorphism 218
  on pre-Palæozoic denudation 219
  on obliterated formations 219
Limestones, primitive 69
  regarded igneous by Emmons 70, 74
  and by others 70 note
  not in Taconic 76
  in Laurentian 123, 125, 127, 128, 151
  saccharoid azoic 157
Logan, Sir William, against Taconic 81
  inclined to yield 82 notes 100
  on red sandrock of Vt. 98
  on Georgia slates 99
  on Pt. Lévis rocks 100
  views of, adopted by Hall 107
  stratigraphic work of 110
  views of, on older works 112
  classification of, in 1845 112
  on rocks of Lake Superior 113
  on an unconformity there 113
  erroneous parallelizing by 114
  on Huron rocks 115-119
  on connection of, with Lake Superior 115
  Huron rocks equivalent to Cambrian 116
  on geology of Bay St. Paul 117
  of Rigaud mountain 117
  on limestones 123, 128
  on L. Temiscamang 123
  on Laurentian system 124
  letter of, to Barrande 125

on conglomerates........ 128
on hypersthene rock............ 129
on Huronian series............130. 131
on Taconic...................... 138
summary of taxonomic views of............................ 138
quoted by Foster and Whitney. 145
Long lake....... 211
Loon lake........................ 178
Lorrain, N. Y.......................72, 111, 112
Lower Canada, geology of......... .. 72
Macculloch on hornblende rock..... 159
Macfarlane on conglomerates. ..120 note
Madawaska........................... 128
Madoc........ ....129, 151
Magnesian slate of Taconic....75, 76, 77, 78
Hitchcock on..... 99
Maine, Taconic in..................... 77
survey of 157
Manual of Geology, Emmons......... 80
Marcou, J. B. on Taconic... ..75 note, 81
correspondence of, with Emmons.......................... 81, 82
on issue between Barrande and Hall.......................... 108
Marvine, A. R. cited.................. 199
Marquette series.......................88, 113
Brooks on 171
N. H. Winchell on............... 183
Rominger on........... 188
Irving on....... 205
Mather, W. W. opposes Taconic.....71, 103
on inversions 94
Matthew, G. F. opinions of........... 156
Mayhew lake 178
Medina sandstone...................... 98
Menominee district.............156, 173, 194
Mesabi range.......................... 204
Metamorphic rocks of lake Superior................... .... 88, 91
of Bay St. Paul........... 117
Metamorphic series of Logan........ 112
term superseded.... 119
Metamorphic theory, Hitchcock on, 95, 96, 97, 98
Metamorphism, C. H. Hitchcock on.. 159
in Michigan..................... 171
in Wisconsin.................... 197
Lawson on................... 218
Mica slate, Hitchcock on 95
Mica schist group................ ... 193
Michigan. Taconic in................. 77, 89
traditional geology in... 170
Michigan, Upper peninsula, Houghton on.......................87, 88, 91
Michipicoten river...................133, 134
Microdiscus quadricostatus...... ...... 79, 80
Mineral region of L. Sup............90 note
Mineral characters, how far to be employed. 163
Brooks on.................... ... 174
Minerals, secondary enlargements of ....201-2, 205 note
Minnesota, map of..................... 184-5
Minnesota river....................... 175
Minnesota rocks tabulated.......... 188
Missisaqui river...................... 130
Missisaqui bay, fault at............. 71
Mississippi river.................... .. 175
Mixed conglomerate and sand rock. 90
Molluscs in Taconic...... 79
Montalban of Hunt.... 152. 153, 154, 155, 156
—— in New Hampshire. 164, 165
not character'tic of Laurentian 168
Montmorenci, geology of 71
Montreal river 90, 195
Mount Marcy named................. 70
Murray, A., on black slates.. .....114 note
on Huron geology..............114, 116
the Quartz Rock, group of...... 116
on the gneisses.............. 118
on conglomerates.............. 118
on Laurentian.............119, 120, 121
on L. Nipissing................121, 122
on Huronian rocks............. 122
Muscovado rock......................... 187
Negaunee 191
Nereites in Taconic.. 77
New Brunswick, geology of.........156, 157
table of opinions on............ 157
literary references on........157 note
New England, Hunt on 151
(See E. and C. H. Hitchcock and Emmons).
New Hampshire, C. H. Hitchcock on 160
table of. by 161
principles to be guided by in... 163
New Hampshire, geology of difficult 160
parallelisms in.......... 167
New Pic river.......................... 134
Newport, R. I........................... 97
New Ulm 183
Nipissing lake................ 121
Norian....... ....151, 152, 153, 154
C. H. Hitchcock on 164, 165, 167
Norway limestone belt,............... 194
Nucleus of the continent located.... 87
Numakagon lake... 197
Ocoee conglomerate. 104
Ogishke conglomerate described...178. 183
thought to be in Animike 136-7
occurring in Rainy lake region 215
recognized on L. Sup. 113, 132 note, 134
Ogishke muncie lake.................. 178
Old Pic river.......... 134
Olenellus thompsoni................. 79
vermontana 79
Olenus asaphoides....................78, 107
vermontana 107
thompsoni 107
Ontarian of Lawson................... 218
Ordovician.............................. 154
Ottawa series............ ....154, 155
Otterhead.... 134
Overturn of crystalline rocks........ 92
Palisade rock.......... 184
Panach lake.................... 123
Paradoxides asaphoides and other species in Taconic;..... 81
Paramorphic changes........... 199
Parry's sound 125
Pebbles, volcanic origin of........... 200
Peltura holopyga................. .....79, 107
Penokee series, Huronian...198, 198 note—equivalents of........ 205
Pewabic quartzyte............ ...186 note
Pic island.............................. 134
Pictured rocks, Houghton on 90
Pigeon point.......................... 175
Pike river............................ 134
Pinckney, N. Y......................... 72
Plumbago brook. 172
Plymouth, Vt........................... 97
Pokegama falls.. 204
Porcupine mountains.............. 201
Porphyritic gneiss..... 166
position of 167, 168
Potsdam, next to Primitive.......... 70
not Taconic 79
finally included. 82
at L. Superior....... 90
synchronized with red sandrock, Vt......................... 90
base of Palæozoic...... 104
not the base.................... 104
in Tennessee...... 104
equivalent of Baraboo quartzyte............... 195
(see lake Superior sandstone).
Preglacial denudation.......... ....211, 219
Primary rocks.classified by Emmons 74
by Houghton. 87, 88, 91
Primordial fossils in Vt..... 106
in eastern N. Y................ 112
Primitive rocks of Emmons......... 69. 78
Prince Edward's island...........157 note
Principles guiding in N. H. geology. 163
Pulaski, N. Y........................ 72
Pumpelly, R , cited......... 199
Quartzyte group......................190, 192

Quartzyte sedimentary in origin.... 172
Quartzytes in Animike.............. 176
Quebec, geology of.................... 72
Quebec group.....................108, 126, 138
defined.............. 138
literature of............ 139
position of.............. 153
Quinnesec ore formation............. 194
Rainy lake..................... 210
geology of..................213, 214, 215
Rat-root bay...................... 215
Red formation in Minn..............184, 202
Red rock at Grand Recollet fall. ..121, 122
Red sandrock of Lake Superior..90, 91, 142
of Vermont 98, 100
Rennselaer county 72, 80
Republic mountain................... 171
Rhode Island, Taconic in............ 77
Rice's Point...................... 201
Rodman, N. Y..................... 72
Rogers, H. D., opposes Taconic 70, 76, 77, 79, 102, 103
on Appalachian overturn. 94, 101, 106
views of, on older rocks.......... 101
on flexures..................... 103
Rogers brothers oppose Taconic..... 77,94
on Appalachian inversions.....95, 109
endorsed by Hall................ 109
Rogers, W.B.,in opposition to Hitchcock.......................... 97
Rominger, C., cited.................. 156
views of......................188 seq.
skepticism of relative to Huronian and Laurentian......188, 189
dissents from Brooks........... 189
divisions of proposed 190
on number of iron horizons.... 192
on the quartzytes 192
on l'Anse slates 193
on mica schist group............ 193
on Menominee district.......... 194
parallelism of Marquette and Menominee 195
Saccharoid limestone................ 157
Saganaga lake.......................179, 183
Saint Joseph's island 88
Saint Mary's river.................... 88
Sandstones associated with conglomerates 90, 91
Sawteeth mountains................. 201
Scapolite rock..................... 92
Schoolcraft. H. R., cited............. 87
Schuylkill river, geology near....... 106
Sedgwick. Cambrian of............... 76
Selwyn, A. R., on Emmons' geology of Montmorenci................ 71
Serpentine group 190, 194
Serpentine. regarded as eruptive by Emmons 74
described by Houghton........ 89
in Massachusetts.............. 92
origin of, according to E. Hitchcook........................ 93
in the Laurentian.............. 128
in Vermont 159
in Canada.................... 216
Slate conglomerate...112, 113, 123, 130, 132-3
Lawson on 209
Slate dykes 172
Smith (S. C.) mine 172, 193
Sparry limestone of Taconic........ 75, 77
omitted........................ 78
Hitchcock on 99
Steatite and serpentine.............157, 159
Stockbridge limestone in Taconic...75, 76, 77, 78 83,
Hitchcock on 99
Sturgeon river....................... 130
Sugar island 88
Superior, lake, geology of, in 1846..112, 114
Susquehannah river................ 401
Taconian as a term................ 153
Hunt on........................154, 155
Taconic ideas discussed in 1841 70
Taconic range........................ 75
Taconic slate 75, 76, 78
Hitchcock on 99
Taconic system, opposers of....70, 75, 76, 77, 102, 103, 138
earliest conception of.......... 74
chapter on 74, 76
description of.................. 75
criticisms on................... 75
unfossiliferous................. 76
equivalent to lower Cambrian. 76
volume on...................... 76
grounds of defense of...........77, 81
fossiliferous 77
extended geographically....... 77
defined later....................79, 81
as finally left.................. 82
literature on.................82-87, 139
in Michigan..................... 91
sustained by Hitchcock......... 101
criticised by H. D. Rogers...... 102
synonym of "Azoic"........... 144
N. H. Winchell on 184
Taconic, upper 78
lower 78
made equivalent to "Hastings series"....................... 153
Taghkanic system announced....... 73
Talcoid schists of Hitchcock......... 99
Taylor mine......................... 193
Teal lake slate dyke................. 172
Temiscamang lake 123, 124, 130
Tennessee, geology of, by Rogers... 104
by Safford ....104, note
Terranovan series of Hunt 152
Tertiary of Emmons.................. 69
distribution of.................70 note
Thessalon river and valley......88, 113, 130
Thompson on St. Louis river. slate at 177
Thunder bay............134, 136, 137, 200, 204
Topography and mineral resources of N. Y., by Emmons.............. 72
Transition of Emmons............ 69, 72, 78
Trap rocks of Lake Superior 88, 137
Trenton limestone.................. 72
Troost, Dr. G., on Appalachian inversion 91
Tudor, Eozoön in.................... 151
Unconformity in Penokee Gap...... 173
skepticism on, expressed....... 173
Unconformity recognized at L. Sup. 113
Van Hise, C. R., cited............... 198
on enlargements of minerals... 205
Vanuxem, L., favoring Taconic, 70 note, 81
quotation from..........106-7 note
Vennor, H., on Hastings series....... 151
Vermilion group 185
Vermilion lake rocks. . 132, 156, 175, 183, 206
Vermont, geological survey of....... 157
Virginia, geology of 104
Vogdes, A. W., suggestions from..... 79
Wadsworth, M. E., on conglomerates 97
Walcott, C. D., antagonizes Taconic 83
Wahnapitæ lake....................123, 130
Washington county, N. Y............ 72
Washington, Mt...................... 166
Waterville, N. H., gabbro in.......... 166
Whitefish river and lake........122, 123, 130
White Mts., geology of, by Hunt.. .151, 152
various opinions on..........164, note
C. H. Hitchcock on.............. 167
Whitney and Wadsworth on "Azoic system" 66, 67
on cupriferous rocks............ 113
Whitney, J. D., quoted.............90 note
opinions of....................140 seq
taxonomic table by 140
on iron-bearing rocks........... 143
on origin of iron ores............ 146
reply of, to Logan............... 147-9
on *Eozoön*........................ 148-9
Wichman, A., cited.................. 173
Winchell, A., American opinion on the older rocks, ... 65
preparation for treatment of... 66
some views of, on Minnesota

rocks........................179, note
Winchell, H. V., on diabasic schists. 211
Winchell, N. H., opinions of.........175 *seq*
on geology of Minnesota river. 175
tour by, in 1878 175
on the hills in N. E. Minn 176
queries by 177
tour by, in 1879.................. 177
on Ogishke conglomerate....... 178
on succession of rocks...... 179
on equivalency of Animike and Kewatin............ 179-80
on thin sections of cupriferous rocks.......................... 181
on crystalline rocks of northwest. .. ..181 *seq*
table of equivalences........... 182-3
on the term Taconic 184
on original Huronian 185
on equivalences in Minn 185
on some general conclusions... 185
on conglomerates in crystalline horizons 185-6
on position of Ogishke conglomerate 186-7
on problems outstanding....... 187
Winooski gneiss 158
Wright, C. E., cited............. ...192, 197

VIII.

ADDITIONS TO THE LIBRARY SINCE THE REPORT OF 1884.

Albany. New York State Museum of Natural History. Annual reports, 36-39. Bulletin, 1, 2, 4-6.

Altenburg. Naturforschende Gesellschaft des Osterlandes. Mittheilungen, III.

Austin. State Geological and Scientific Society. Bulletin, I, 3 and 12.

Baltimore. American Chemical Journal, vii; viii; ix, 1, 2, 4-6; x, 1, 2, 4-6; xi; xii, 1-7. General Index to Vols. i-x.

Basel. Naturforschende Gesellschaft. Verhandlungen, viii, 1-3.

Belfast. Naturalists' Field Club. Annual report, iii, 1.

Belgrade. Institut Geologique. Annales Geologique de la Péninsule Balkanique. Tome 1.

Bergen. Bergens Museum. Aarsberetning, 1885-88.

Berlin. Gesellschaft für Erdkunde. Verhandlungen, xvi, 1-6. Zeitschrift xxv, 1 3.

Bern. Naturforschende Gesellschaft. Mittheilungen, 878-1214.

Boston. American Academy of Arts and Sciences. Proceedings, xvi.

Bremen. Natur-wissenschaftlicher Verein. Abhandlungen, x; xi, 1, 2.

Brooklyn. Public Library. Annual report, 31.

Brünn. Natur-forschender Verein. Verhandlungen, xxiii—xxvii. Bericht, der Meteorologischen Commission, 1883-1887.

Bruxelles. Société Entomologique de Belgique. Compte Rendu, iii, 99-102; 117-120.

Budapesth. Ungarischen Geologischen Gesellschaft. Mittheilungen, xvi; xvii, 1-6, 9-12; xviii; xix; xx, 1-4.

Buffalo. Society of Natural History, v, 1, 2.

Cambridge. Appalachian Mountain Club. Appalachia, iv, 2, 3; v, with map; vi, 1. Register for 1890.

Museum of Comparative Zoology. Bulletin, v; xii, 1-6; xiii, 1-4, 6-10; xiv, xv; xvi, 1-8; xvii, 1-6; xviii; xix, 1-4; xx, 1. Annual report, 1885-1888.

Peabody Museum of American Archæology and Ethnology. Annual report, 18-22.

Canada. Geological Survey. Annual report, ii, with maps; iii, 1, 2, with maps.

Champaign. Illinois State Laboratory of Natural History. Bulletin, i; ii, 1-6; iii, 1-3, 7. Ornithology of Illinois, vol. i.

Chapel Hill. Elisha Mitchell Scientific Society. Journal, v; vi; vii, 1.

Christiania. Meteorologiske Institute. Jahrbuch, 1885-1887.

Cincinnati. Society of Natural History. Journal, xii, 4; xiii, 1, 2.

Colorado Springs. Colorado College Studies. Annual, i.

Columbus. Agricultural Experiment Station. Bulletin, i, 1.

Darmstadt. Verein für Erdkunde. Notizblatt, iv, 6-10.

Geologischen Landesanstalt. Abhandlungen, i, 3, 4.

Davenport. Academy of Natural Sciences. Proceedings, iv; v, 1.

Denver. Colorado Scientific Society. Proceedings, ii, 2, 3; iii, 1.

Dresden. Verein für Erdkunde. Litteratur des lands und volkskunde des königsreichs Sachsen.

Dublin. Royal Dublin Society. Proceedings, iv, 7-9; v; vi, 1-6. Transactions, iii, 7-14; iv, 1-5.

Edinburgh. Geological Society. Transactions, iv, 3; iv, 1-4. Catalogue of library.

Royal Society. Proceedings, xv; xvi.

Frankfort. Geological Survey of Kentucky. Kentucky fossil shells. A monograph of the fossil shells of the Silurian and Devonian rocks of Kentucky. H. Nettleroth. Preliminary map of Kentucky. J. B. Hoeing.

Giessen. Oberhessischen Gesellschaft für Natur und Heilkunde. Bericht, xxvi; xxvii.

Glasgow. Geological Society. Transactions, vii, 2; viii, 2.

Philosophical Society. Proceedings, xx.

Granville. Denison Scientific Association. Bulletin, i; ii, 1, 2.

Gustrow. Verein der Freunde der Naturgeschichte in Mecklenburg. Archiv, xliii.

Halifax. Nova Scotian Institute of Natural Science. Proceedings, i, 4; ii; iii, 1, 3; iv; v; vi; vii, 3.

Hanover. Naturhistorische Gesellschaft. Jahresbericht, xxiv-xxxiv.

Iglo. Ungarischen Karpathen Verein. Jahrbuch, vi-xvii.

Indianapolis. Geological Survey. Annual report, xv.

Iowa City. Laboratories of Natural History, University. Bulletin, i, 1-4.

Jefferson City. Geological Survey. Bulletin, i.

Karlsruhe. Naturwissenschaftlicher Verein. Verhandlungen, x.

Kiel. Natur-wissenschaftlicher. Verein für Schleswig-Holstein. Schriften, iii-vi.

University. 95 pamphlets, mostly inaugural dissertations.

Kiew. Société des Naturalistes. Mémoires, iii-viii; ix, 1, 2, supplement; x; xi, 7.

Klagenfurt. Naturhistorischen Landes—Museums von Kärnten. Jahrbuch, xxxv; xxxvii. Diagramme, 1885-1889.

Königsberg. Physikalisch-œkonomische Gesellschaft. Schriften, 1876-1889, Duplicated for 1879-1889.

Lansing. Board of Agriculture. Annual report, xxviii.

Leipzig. Verein für Erdkunde. Mittheilungen, 1887, 1888.

Lille. Société Géologique du Nord. Annales, xv, 2 copies.

Lincoln. University studies, I, 7.

Lund. University. Acta universitatis Lundensis, xxv.

Lüneberg. Naturwissenschaftlicher Verein. Jahresheft, xi.

Madison. Wisconsin Academy of Sciences. Transactions, vii, State Historical Society. Catalogue of library, i-vii.

Mendon. American Antiquarian, vii; 4-6; viii, ix; x; xi; xi, 7.

Meriden. Scientific Association. Transactions, iii.

Mexico. Sociedad Cientifica "Antonio Alzate." Memorias, i; ii; iii, 7-8. Observatoire Meteorologique Central de Mexico. Boletin Mensual, I; II, 1-9. Annales del Ministerio de fomento de la Republica Mexicana, viii. Informes y documentos relativos à Comercio Interior y Exterior Agricultura, Mineria é Industrias, 49, 51-59. Informe que la Comision para la destruccion de la langusta.

Minneapolis. Academy of Natural Sciences. Bulletin, iii, 7. American Geologist, i-v; vi, 1-4.

Montreal. Canadian Record of Science, i, 3, 4; ii, 1, 2, 4-8; iii, 1-3, 7; iv, 3.

Moscou. Société Imperiale des Naturalistes. Bulletin, 1884, iv; 1885-1888; 1889, i-iii. Beilage, 1885-1889. Nouveaux Memoires, xv, 4, 6.

New York. Academy of Sciences. Transactions, iii; v. Annals, iii, 9, 10; iv; v, 1-3. American Geographical Society. Bulletins, xxi, Supplement; xxii, 1, 2. American Museum of Natural History. Annual report, 1887-88: 1889-90.

New Zealand. Colonial Museum and Geological Survey. Annual reports 20-23. Report of Geological explorations, xvii; xviii; xix. Index to reports of the Geological Survey of New Zealand from 1866 to 1885. Meteorological report, 1885. Official record of the New Zealand Industrial Exhibition of 1885. Studies in biology for New Zealand students, iii. Manual of the New Zealand Coleoptera, vii.

Norway. The Norwegian North Atlantic Expedition, 1876-1878, xv-xix.

Nürnberg. Natur-historische Gesellschaft. Jahresbericht, 1887, 1888. Festschrift zur Begrüssung des 18de Kongress der Deutschen Anthropologischen Gesellschaft.

Paris. Société Zoologique de France. Bulletin, i-xiii; xiv, 1-10; xv, 1-5. Mémoires, i; ii; iii, pp. 1-96.

Philadelphia. Academy of Natural Sciences, 1888; 1889; 1890, i. American Naturalist, xxii; xxiii, 265-269, 271-276; xxiv, 277-284. Wagner Free Institute. Transactions, 1.

Reno. Agricultural Experiment Station. Bulletin, 8.

Rio de Janeiro. Museo Nacional Archivos, vii.

Salem. Peabody Academy of Science. Annual reports of the Trustees, 1874-1884; 1886; 1887.
Conventionalism in ancient American Art.

St. Anthony Park. Agricultural Experiment Station. Bulletin, ix.

St. Louis. Academy of Science. Transactions, iv, 4; v, 1, 2.

S. Paulo. Commisséo Géographica é Geologica da Province S. Paulo. Boletin, i-iii.

St. Petersburg. Comité Geologique. Mémoires, i. 1-4; ii, 1. Bulletin, i-vii.

San Diego. West American Scientist, ii, 14, 15, 17.

San Francisco. California Academy of Sciences. Bulletin, i; ii. Proceedings, i; ii.
State Mining Bureau. Annual reports, v-vii; ix.

San Jose. Instituto Meteorologico Nacional. Boletin, 1888, 1-2, 4.

Santiago. Deutschen Wissenschaftlichen Verein. Verhandlungen, v.

Stettin. Verein für Erdkunde. Jahresbericht 1886, 1887, 1888.

Stockholm. Institut Royal Geologique de la Suède, Series C, 29, 63, 65, 67-111, 113-115.
Entomologisk Tidskrift, viii-x. Geologiska Förening. Förhandlingas, xi.

Sydney. Free Public Library. Report from Trustees for 1888-89.

Topeka. Kansas Academy of Sciences. Transactions, x; xi; xii, 1.
Washburn Laboratory of Natural History. Bulletin, i; ii, 8-11.

Toronto. Canadian Institute. Proceedings, iii, 3, 4; iv-vi; vii, 1.
Public Library. Catalogue.
Royal Commission. Mineral resources of Ontario, 1890.

Trenton. Natural History Society. Journal, i, 2.

Upsala. University. Arsskrift, 1886, 1887, 1888.

Washington. National Museum. Proceedings, xii, 773, 776, 777, 779-788, Index; xiii, 790, 791, 794-814. Bulletin 38.

Philosophical Society. Bulletin, i-iv; vi-ix; x, pp. 1-40. A memoir of Joseph Henry. By Wm. B. Taylor.

Proceedings at a meeting commemorative of the life and scientific work of Spencer Fullerton Baird.

Smithsonian Institution, annual reports, 1882, 1883, 1884, 1885, 1886, 1887. Report upon International Exchanges, Register of the War Department, 1889. Official Congressional Directory, 1889. United States Geological Survey. Annual report iv-vii; viii, 1, 2. Bulletins, vii-lvii. Monographs, v-xi; xii, with atlas; xiii; xiv; xv, 1, 2; xvi.

Mineral resources of the United States, 1883-84, 1885, 1886, 1887.

Wien. K. K. natur-historischen hof-museums. Annalen, i-iv; v, 1, 2. K K. Zoologisch-botanischen Gesellschaft. Verhandlungen, xxxiii-xxxix; xl, 1, 2.

DONATIONS.

Borneman, John G. Die versteinerungen des Cambrischen Schichtensystem des Insel Sardinien.

Brauns, D. Das problem des Serapemus von Pazzuoli.

Clark, W. B. Ueber die geologische verhältnisse der Gegend nordwestlich vom Aachen See.

Danielson, D. C. and J. Koren. Fauna littoralis Norvegiæ. Part 1-3.

Dawson, G. M. The mineral wealth of British Columbia.

Frazer, Persifor. The Archean Palæozic Contact near Philadelphia, Pa.

Archean characters of the rocks of the nucleal ranges of the Antilles.

Fuchs, Edmond. L'Isthme de Corinthe, sa constitution geologique. 3 copies.

Notice necrologique sur A. E. Beguyer.

Notice sur la constitution des Gites die Phosphate de Chaux.

Gorman, H. A preliminary report on the animals of the waters of the Mississippi bottoms.

Gatschet, A. S. Six excerpts on ethnological subjects.

Geinitz, F. Eng, Die Blattinen aus der unteren Dyas.

Das Erdbeben von Iquique am 9 Mai, 1877.

Die Skandinavischen Plagioclas gesteine und Phonolith.

Gerster, C. Die Planer-bildungen um Ortenburg bei Pastan.

Hehl, R. A. Von den vegetabilischen Schätzen Brasiliens und seiner Bodencultur.

Helland, A. Lakis kratern og lava strömme.

Hensoldt, H. A naturalist's rambles in Ceylon.

Jensen, O. S. Turbellaria ad litora Norvegiæ occidentalis.

Lévy, A. Michel. Sur une gisement francais de Melaphyres à Enstatite.

Lindahl, J. Thirteen excerpts on zoological subjects from the Kongl, Vetenskaps Akademiens, Handlingar.

Löfstrand, G. Om apotitens forekomst i Norrbottens län.

Marcou, J. American geological classification and nomenclature.

Nausen, F. Bidrag til Myzostomernes anatomi og histologi.

Ochsenius, C. Beiträge zu Erklärung der bildung von Steinsalzlagern.

Pohling, Hans. Dentition und kranologi des Eliphas antiquus Fole.

Reusch, Hans. Bommeloen og Karmoen med amgivelser geologisk beskrevne

Rutley, Frank. Rock-forming minerals.

On Trachyte from Victoria Park.

Stenzel, Gustav. Die Gattung Tubicaulis Cotta.

Snow, F. H. On the discovery of a fossil bird-track in the Dakota sandstone

Ulrich, E. O. Contributions to the Micropalæontology of the Cambro-Silurian rocks of Canada. Part II.

Zinken, C. F. Die geologischen horizonten der fossilen Kohlen.

BY PURCHASE.

Noxious and beneficial insects of the state of Illinois: Reports 6-11.

Insects injurious to agriculture. By P. R. Hoy.

On the genera of Aphidæ found in the United States. By Benj. D. Walsh.

Spiders of the United States. By N. M. Hentz.

The water-power of Maine. Walter Wells.

List of the Coleoptera of America north of Mexico. Samuel Henshaw.

Remarks on synonyms of European spiders. Parts 1-4. T. Thorell.

On European spiders. T. Thorell.

Schoolcraft's Mississippi river. Summary narrative.

Butterflies of the Eastern United States. G. H. French.

Enumeratio Hemipterorum. Parts 1-5. C. Stal.

32 papers on iron ores. Purchased from A. E. Foote.

Annual reports of the Commissioner of Mineral Statistics of Michigan for 1880 1881 and 1884.

Mines, miners and mining interests of the United States in 1882. Balch.

PUBLICATIONS OF THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

I. ANNUAL REPORTS.

The First Annual Report on the Geological and Natural History Survey of Minnesota, for the Year 1872. 112 pp., 8vo.; with a colored map of the state. By *N. H. Winchell*. Published in the Regents' Report for 1872; Second edition identical.

The Second Annual Report on the Geological and Natural History Survey of Minnesota, for the Year 1873. 145 pp., 8vo.; with illustrations. By *N. H. Winchell* and *S. F. Peckham*. Published in the Regents' Report for 1873. Out of print.

The Third Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1874. 42 pp., 8vo.; with two county maps. By *N. H. Winchell*. Published in the Regent's Report for 1874. Out of print.

The Fourth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1875. 162 pp.; 8vo.; with four county maps and a number of other illustrations. By *N. H. Winchell*, assisted by *M. W. Harrington*. Also in the Regents' Report for 1875. Out of print.

The Fifth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1876. 248 pp.; 8vo.; four colored maps and several other illustrations. By *N. H. Winchell*; with reports on Chemistry by *S. F. Peckham*; Ornithology by *P. L. Hatch*; Entomology, by *Allen Whitman*; and on Fungi, by *A. E. Johnson*. Also in the Regents' Report for 1876. Out of print.

The Sixth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1877. 226 pp.; 8vo.; three geological maps and several other illustrations. By *N. H. Winchell*; with reports on Chemical Analyses, by *S. F. Peckham*; on Ornithology, by *P. L. Hatch*; on Entomology, by *Allen Whitman*; and on Geology of Rice county, by *L. B. Sperry*. Also in the Regents' Report for 1877. Out of print.

The Seventh Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1878. 123 pp.; 8vo.; with twenty-one plates. By *N. H. Winchell*; with a Field Report, by *C. W. Hall*; Chemical Analyses, by *S. F. Peckham*; Ornithology, by *P. L. Hatch*; a list of the Plants of the north shore of Lake Superior, by *B. Juni*; and an Appendix, by *C. L. Herrick*, on the Microscopic Entomostraca of Minnesota; twenty-one plates. Also in the Regents' Report for 1878. Out of print.

The Eighth Annual Report on the Geological and Natural History Survey of Minnesota, for the year 1879. 183 pp.; 8vo.; one plate (Castoroides). By *N. H. Winchell*. Containing a statement of the methods of Microscopic Lithology, a discussion of the Cupriferous Series in Minnesota, and descriptions of new species of brachiopoda from the Trenton and Hudson River formations; with reports on the Geology of Central and Western Minnesota, by *Warren Upham*; on the Lake Superior region, by *C. W. Hall*; lists of birds and of plants from Lake Superior, by *Thomas S. Roberts*; Chemical Analyses, by *S. F. Peckham*; Report by *P. L. Hatch*; and four Appendixes. Also in the Regents' Report for 1879 and 1880. Out of print.